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EVALUATION OF MEDICAL RESPONSE IN DISASTER PREPAREDNESS

With special reference to full-scale exercises

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Karolinska Institutet

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"The plan is useless; it's the planning that's important"

(Dwight D. Eisenhower)

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Evaluation of Medical Response in Disaster Preparedness
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ABSTRACT

Background: Disaster exercises and simulations serves as teaching and training tool for improving medical response in disaster preparedness. Rapid and effective medical response in major incidents is known as a “key phase” to optimise resources, and this requires that management systems have an “all hazards” approach. Decision-making at all levels of management is based on available information and involves allocation of medical resources and triage decisions. **Aim:** The overall aim of this thesis was to increase our knowledge of the impact of quantitative evaluation of medical response on disaster preparedness. The specific aims were: to increase the ability to learn from full-scale exercises by applying quality indicators at two levels of command and control (I, II); to identify key indicators essential for initial disaster medical response registration (III); to explore ambulance staff attitudes towards practising triage tagging (IV); and to increase our knowledge of the applicability of a technical support system and its potential to provide real-time, overall situation awareness available to those overseeing the medical management of the operation. **Methods:** Study I, II and V were observational studies based on data collections from full-scale exercises. Templates with measurable performance indicators for evaluation of command and control were used in Study I and II and the same performance indicators combined with outcome indicators was also included in Study II. A consensus method, the Delphi technique, with 30 experts was used in Study III. Study IV used mixed methods, a pre-and post web survey answered by ambulance nurses and physicians (n=57 respectively 57) before and after a time limited strategy with triage tags and three focus groups interviews comprising 21 ambulance nurses and emergency medical technicians. Study V used major two incidents simulations to test the applicability of Radio Frequency Identification (RFID tags) technology and compare it with traditionally paper-based triage tags (n= 20 respectively 20). The quantitative data were analysed using descriptive statistics, and content analysis was used for the qualitative data. **Results:** The evaluation model exposed several problems occurring in the initial decision-making process that were repeatedly observed (I, II). These results in study II also demonstrated to have a major impact on patient outcome.Out of 17 severely injured patients five respectively seven were at risk for preventable death. A total of 97 statements were generated, of these 77 statements reached experts consensus, and 20 did not (III). Ambulance staffs believe in the usefulness of standardised triage methods, but the sparse application of triage tags at the scene indicates that the tags are not used frequently. Infrequent use in daily practice prevents participants from feeling confident with the triage tool (IV).The Radio Frequency Identification system improved situational awareness in disaster management. Triage information was available at least one hour earlier compared to a paper-based triage system (V). **Conclusions:** The presented evaluation model can be used in an objective, systematic and reproducible way to evaluate complex medical responses, which is a prerequisite for quality assurance, identification of problems, and the development of disaster preparedness.

Key words: Air crash, Delphi method, disaster, evaluation, simulation, response, preparedness, triage, Radio Frequency Identification, lessons learned, patient outcome, content analysis

LIST OF PUBLICATIONS

This doctoral thesis is based on five studies, referred to by their Roman numerals I-V. In study V the first two authors share first authorship*.

I. Gryth D, **Rådestad M**, Nilsson H, Nerf O, Svensson L, Castrén M, Rüter A. Evaluation of Medical Command and Control using Performance Indicators in a Full-Scale, Major Aircraft Accident Exercise. *Prehospital Disaster Medicine 2010; 25(2):118-124.*

II. **Rådestad M**, Nilsson H, Castrén M, Svensson L, Rüter A, Gryth D. Combining performance and outcome indicators can be used in a standardized way: a pilot study of two multidisciplinary, full-scale major aircraft exercises. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine 2012, (1) 20:58.*

III. **Rådestad M**, Jirwe M, Castrén M, Svensson L, Gryth D, Rüter A. Essential key indicators for disaster medical response suggested to be included in a national uniform protocol for documentation of major incidents: a Delphi study. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine 2013, 21:68.*

IV. **Rådestad M**, Lennquist Montán K, Rüter A, Castrén M, Svensson L, Gryth D, Fossum B. Attitudes and experiences of triage tags in major incidents from the users view: a mixed method study. *In manuscript*

V. Jokela J*, **Rådestad M***, Gryth D, Nilsson H, Rüter A, Svensson L, Harkke V, Luoto M, Castrén M. Increased Situation Awareness in Major Incidents-Radio Frequency Identification (RFID) Technique: A Promising Tool. *Prehospital Disaster Medicine 2012; 27(1):81-87.*

CONTENTS

LIST OF ABBREVIATIONS

DMR	Disaster medical response
ED	Emergency Department
EDC	Emergency Dispatch Centre
EMCC	Emergency Medical Communication Centre
EMS	Emergency medical services
ETS	Emergo Train System™
FGI	Focus Groups Interviews
FSE	Full-scale exercise
GPS	Global Positioning System
GSM	Global System for Mobile Communications
MACSIM	Mass Casualty Simulation System™
MI	Major incident
NBHW	National Board of Health and Welfare
NGO	Non-Governmental organisation
NGT	Nominal Group Technique
PI	Performance indicators
SCC	Stockholm county council
RFID	Radio Frequency Identification
WHO	World Health Organisation

1 INTRODUCTION

At around 10:26 local time on the 25 of February 2009 an aircraft crashed when attempting to land at Schiphol international airport Amsterdam. The aircraft was Turkish Airline, flight TK 1951, from Istanbul. Nine of the 135 passengers and crew died on the scene and 120 were wounded [1, 2].

The number of commercial aircraft crashes and victims has decreased over the last decade, even so approximately 1,000 individuals are killed in accidents each year. Hence, rigorous regulations make it obligatory for commercial airports to test their airport rescue response capability on a regular basis [3, 4]. Field exercises are performed every other year to test plans and management procedures in order to improve interagency coordination and communication.

Almost one year before flight TK 1951 crashed, on the 9th of October 2008, a multidisciplinary full-scale, major aircraft accident exercise was conducted at a major airport in Sweden in order to simulate, as closely as possible, a real flight disaster. As in the case of the Amsterdam disaster one year later the plane crashed while attempting to land. Of the 100 simulated passengers and crew, nine died on the scene and 90 were wounded. Field exercises like this are often criticised for being expensive to plan and execute, and also for lack of realistic timetables of incident management and response and adequate evaluation tools. If we are to deal with this we must have good education, training and evaluations methods. This thesis addresses some of the gaps that are crucial to scientific knowledge and the need for evaluation methodologies of medical response in disaster preparedness. The accuracy of triage is essential in medical response [5]. This thesis also covers ambulance staff attitudes towards use of a paper-based triage tool in mass casualty situations and the use of a technical support system called Radio Frequency Identification (RFID).

2 BACKGROUND

2.1 PRESENT STATUS

In a global perspective the frequency and severity of disasters has increased and continues to increase [6]. Disasters often result in significant impacts on public health, including the loss of lives [7]. Due to consequences of increased urbanisation the risk for major incidents (MIs) resulting in mass casualties also increases. The world's population is estimated to grow from 6.1 billion in 2000 to approximately 9 billion in 2050 [8]. Public health consequences of disasters, in terms of morbidity and mortality as well as property damage and costs, have reached astounding levels during recent decades [9, 10]. The primary objective of any disaster medical response (DMR) is to mitigate its effects on health and to obtain the best possible outcome for the greatest number of individuals affected [11, 12].

Trauma is the main cause of death among peoples under 45 years of age in Sweden, as in most other developed countries [13]. However, compared to many other countries the incidence of major trauma in Sweden is lower [14]. This is mainly due to relatively safe transport systems and working environment few natural disasters and antagonistic incidents [15]. This relatively low incidence of major trauma favours a system that allows emergency medical services (EMS) and health care providers to follow their "doctrine of daily routine" even in a major incident situation. Since few individuals in the health care system have extensive experience, planning, preparedness, education and training plays an important role in preparing EMS providers [16] . Exercises can be of significant value but in the current literature it is stated that they are infrequently conducted and that skills that are not used regularly will quickly be forgotten [17]. It is well known that procedural skills tend to deteriorate with the passage and this is described as the retention curve [18].

Several reviews have addressed the best way of training EMS providers in disaster response in order to improve preparedness [9, 19]. However, the available evidence is limited as to whether training interventions are effective in improving response in the disaster situation [9, 10, 20, 21]. Moreover, there are few objective data in the literature that evaluate the retention of skills gained from training sessions [22]. Knowledge and skills are forgotten if EMS personnel are not able to practice or perform frequently [14, 17, 23]. Put simply, an effective learning process is often based on repetition [24]. Even myths concerning disaster management can emerge such as misconceptions and difficulties in sharing knowledge between researchers, instructors and practitioners [3, 23]. Alexander [25] undertook surveys among students (US) and trainee emergency managers (Italy) from two countries about disasters and disaster management, indicating that some disaster myths are strongly believed internationally.

2.1.1 Disaster medicine

Disaster medicine is a multidisciplinary field related to medicine (e.g. emergency medicine, surgical disciplines and anaesthesiology) [3, 17]. In disaster medicine, however, evidence-based guidelines on best practice are limited [3, 26, 27]. Research in disaster medicine is mainly retrospective since prospective data are difficult to collect during an actual disaster [12, 21, 26-30]. Reports in the literature have mainly been descriptive with limited external validity (in this context comparison with other incidents). It is also doubtful that the same experiences reported time after time for decades, can lead to lessons learned [27, 31-33].

Research on disaster medical response (DMR) is sparse. The challenge of collecting reliable information remains, since research tools may not be validated, available, or possible to administer during the complexity of a disaster [21]. Yet, improvement in the documentation of disasters is an important issue for DMR evaluation and research. Systematically analysed results from training exercises may be the best way of gaining new knowledge and should be viewed as a means of continuous quality improvement [17]. This requires the development of validated evaluation tools. Since a real incident is not the time or place for education and training, disaster simulation is frequently used to serve as a basis for improving planning and preparedness [17]. Until recently research has largely been based on the analyses of descriptive empirical data based on interviews of those partaking in the incident [27]. However, there is an increasing interest in quantitative research [30, 33]. The use of standardised methods is necessary if evaluation and the results of research are to be valid and comparable[30].

2.1.2 Framework for disaster health education and training

The world Association for Disaster and Emergency Medicine (WADEM) is an international scientific and multidisciplinary organisation dedicated to disaster health and preparedness [34]. In 2003, the international disaster medicine and emergency health community requested that the WADEM should lead the development of international standards and guidelines on education and training for disaster response in major incidents [35, 36] . The vision of the WADEM “working group” was to develop evidence-based standards and guidelines, internationally applicable in a broad sense for all members of the health-care community. This work was done through an international consultation process, aimed at improving education and training standards [37], and to help structure the evolving field of disaster medicine. An educational framework based upon a conceptual model for disaster health management was presented (Figure 1).

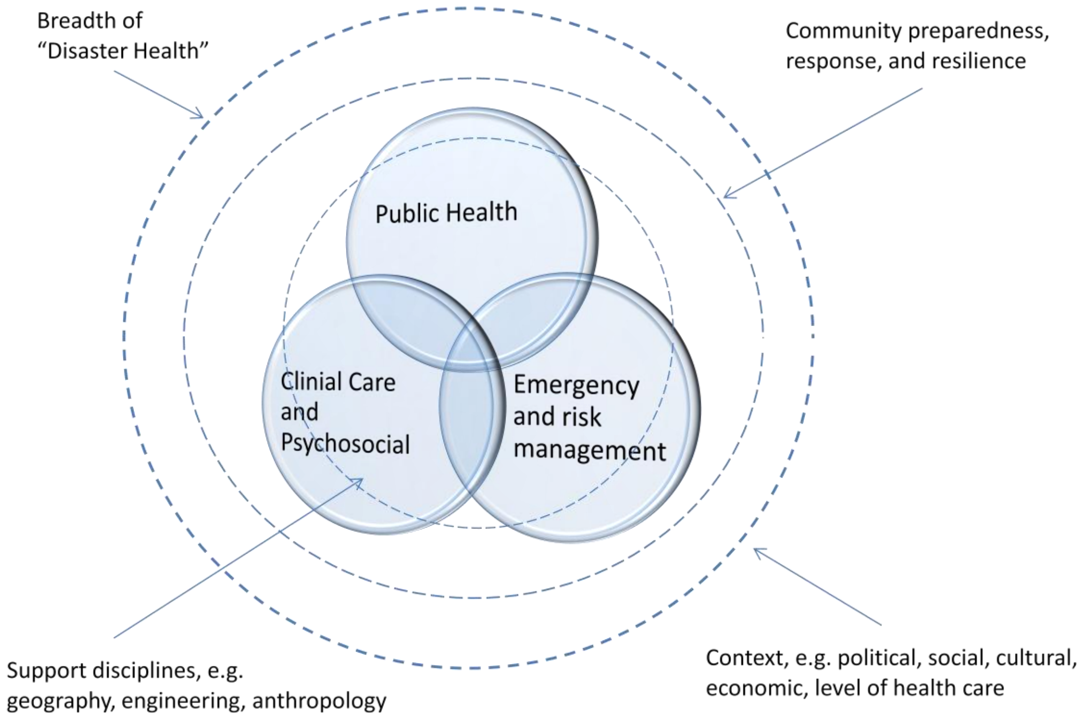

Figure 1. A framework for Disaster Health, which comprises three interrelated core domains after Archer and Seynaeve 2007. Used with permission from Prehospital disaster medicine.

This framework aims to clarify the relationships between public health, clinical care, psychosocial aspects, and emergency and risk management. This implies a reinforcement of the multidisciplinary approach in the field of disaster medicine ,with a broader focus on health management [38], previously the focus has been on emergency management. Recent incidents throughout the world have increased awareness among professionals and in the community of disaster health issues that must be addressed if we are to improve our knowledge and understanding of the core process [39]. This has highlighted the need for increased national and international efforts to support disaster planning and preparedness through evidence-based research and analysis, and at the same time, improve the education and training of medical staff, based on best evidence and practice [39].

Since WADEMs first important steps towards the standardisation of methods of data reporting and validation of education and training models efforts have been made by a number of researcher to strengthen methodological progress in education and teaching in order to reach quality assurance [16, 33, 40-44]. Furthermore, in recent decades technology in the areas of medicine and telecommunication has progressed at an ever increasing rate. Techniques that can be used in decision support system in disaster medical response, design of research studies and conduct of evaluations tools are now easily available [45].

2.1.3 **Disaster vs. Major incident**

What is considered to be a disaster or a MI within a health-care system differs depending on the location, resources and culture where the incident occurs. To be able to manage different situations health care organisations need plans with necessary adjustments according to principles and practice of medical care and resources available [17, 46]. Disaster medical response is of a crucial factor in the shift in focus from the medical care of individuals to the situation of all those affected. The worldwide goal in emergency preparedness is to reduce health consequences for the community in terms of mortality and morbidity [7]. The primary goal of our health care system is to "*reduce or eliminate loss of life and health, and subsequent physical and psychological suffering ",*regardless of the situation [17].

2.1.3.1 Disaster

One definition used by the World Health Organisation (WHO) is *"a sudden ecological phenomenon of sufficient magnitude to require external assistance"* [7]. WHO is the leading agency for addressing health aspects of emergency preparedness and response. However, several other definitions of "disaster" are frequently used [3, 47]. The fact that disaster situations exceed the normal coping ability of MIs, coordinated support from outside the affected community is requested [48]. Attempts have been made by researcher and professionals to find a universally formulated and accepted definition of a disaster [6, 30, 49]. The variation in definitions reflects the different preconditions e.g. differences in resources and structure of communities between countries. It also reflects differences in organisations and authors' opinions [17, 50]. Countries and communities seem to adopt definitions that suit their own preparedness and response contexts . This may lead to difficulties in comparing databases and as a result problem with research.

2.1.3.2 Major Incident

Major incident is defined in the litterature as "*any situations where available resources are insufficient for the immediate need of medical care"* [17] and *"any incident where the location, number, severity, or type of live causalities requires extraordinary resources"* [51] or "*events that owing to the number, severity, type or location of live casualties require special arrangements to be made by the health services*" [52]. These definitions highlights the initial imbalance between the immediate requirements of medical response management and the immediate access to resources, regardless of type of incident or number of casualties [17, 46]. However, while the term MI (including mass casualties) is commonly described in the literature, less attention is given to those incidents with significant disruption of the health care system`s infrastructure. Examples of the latter are disruption of computer or other technical systems, power failure, water and gas supply disruptions [53]. Disruptions of these can have negative impact on hospital capacity and thereby may affect the healthcare system as a whole within a geographic area [54, 55]. In the Swedish emergency preparedness response system the term MI (swe= allvarlig händelse) has an “all hazards” approach i.e. the incident per se is not defined, but the health care system response is the same [56]. Furthermore, management methodology in Sweden has defined MI as an incident having such magnitude or severity that available resources are strained and must be managed, organised and used in a special way as stated in national regulations [56].

2.1.3.3 Swedish emergency preparedness system and nomenclature

Healthcare emergency and disaster medicine is an important part of crisis preparedness in Sweden. The national disaster management structure (doctrine) is described in the national regulation for disaster medicine preparedness issued by the NBHW [56]. According to these regulations, preparedness should be based on five components; 1) planning 2) equipment 3) education, training and exercises, 4) medical management 5) evaluation and follow-up. The Swedish regulations for disaster medicine preparedness play an important role in the planning of, education on and training for the health care systems response. In Sweden, MI is used as a term for situations where the medical management is organised in a specific manner when declared in the immediate medical response. Ambulance services and hospital personnel are expected to respond according to plans and procedures stated in the national regulations. The Swedish disaster management system is organised in three hierarchical levels (Figure 2):

National level- includes management of matters of national interest, contact with other national agencies, and information at top political levels.

Regional (strategic) level – includes management and coordination of the County Council's resources, and contact with other health-care providers and agencies.

Local level - includes management at the scene of the incident and at the receiving healthcare facilities [57].

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Figure 2 Schematic model of Swedish disaster management system where demands and limits are set by the higher level for those lower down

In Sweden, all emergency agencies (e.g. rescue service, police and health care) have mutual responsibility for emergency and disaster preparedness and management (Act 2006:544) [58] despite different legislations. The principle of responsibility implies responsibility of an agency to cooperate, to manage and to accomplish the task at hand. The Swedish Civil Contingencies Agency (MSB) supports and coordinates civil emergency planning and crisis management undertaken by local, regional and national authorities [59, 60]. MSB has also a special responsibility to support and evaluate the civil society´s joint crisis management capability. In Sweden health care services and agencies have to evaluate and self-assess their own disaster preparedness capability, conduct disaster exercises and constantly test and update their disaster plans.
Health-care providers include health-care facility personnel and the EMS, where EMCC (SOS Alarm) and the ambulance service play an essential role in emergency preparedness. The first medical assessment of an emergency call is made at the EMCC by the emergency medical dispatcher (EMD) [61]. The EMD has an essential role in the early stage of incident management by alerting and dispatching the necessary ambulance resources. The Swedish ambulance service are staffed with three different personnel categories; registered nurses, and specialist ambulance nurses, and Emergency Medical Technician (EMT) [62] (and in some areas physicians', usually anaesthesiologists).

In Sweden we have a system with duty officers (DO) for the regional (strategic) and national (NBHW) medical levels, with 24-hour preparedness . Each county council has their own criteria on what comprises a major incident depending on the geographical setting, resources available, time of day, and also depending on the current situation at the receiving hospitals. DO acts as a door opener to the health care services combined resources. The bearer of the role of regional DO has the authority to instantly declare a "major incident" and to act as initial strategic commander over all regional health care resources. The DO normally alerts and receives information from the EMCC or other agencies such as police/rescue services or the county council administration committee [55-57]. There are various levels for alert, with increasing disruption of normal hospital services and technical systems [55]. All data concerning an alert are registered by the DO in a paper-based or web-based log. There is no general accepted uniform log system for collecting or reporting data.

In practice, the terms disaster and MI, that cover a wide spectrum of situations, are frequently used. A traditional classification of disasters is based on an etiology i.e. natural or man-made. This is now being challenged since there should not be any differences in the preparedness or management of an incident based on the etiology [3]. When defining disaster, Koenig et al. [47] presents a model that focuses on the disasters' functional impact on the health care system rather than the incident itself. Moreover, definitions that focus on terminology in the practice of DMR have been highlighted in the literature, and this is useful for disaster preparedness and research [17, 50].

2.1.4 **Disaster management**

A hazard is defined as any phenomenon that cause disruption or damage to individuals and their environment [7]. Globally nations and communities are vulnerable to a wide range of hazards. An effective response to a major incident should be based on an "all hazards" approach. This is defined as the universal ability to adapt and apply fundamental disaster management principles to any MI, regardless of cause [63]. A management system should provide a structure for organisation of resources and responsibilities for anticipating and dealing with hazards in order to mitigate the impact and the possibility of disaster [8]. This process from hazard to disaster was described in 2003 by Sundnes and Birnbaum (Figure 3) [30].

Figure 3 Process from hazard to disaster presented as ripples, modified after Diagrammatic representation of definitions [30] (WADEM 2003).

The impact of a disaster may include damage to property, loss of life, injury, disease and other negative effects on human mental well-being. It requires complex responses involving multiagency assistance including emergency services, governmental organisations and non- governmental organisations (NGOs) [8, 64].

There are four phases in disaster management often expressed in terms of functional activities, components or aspects [3, 48] These phases are 1) planning/preparedness, 2) response, 3) recovery and 4) prevention/mitigation illustrated as part of an unbroken chain of processes (Figure 4). Instead of focusing on response alone, disaster management represents all aspects of risk management. The phases have been used for many decades to help organise the practice of emergency and disaster management using a proactive approach [65]. However, various graphics describing the same processes can be found in textbooks, on web sites and reports, and other published material. The studies in this thesis particularly focus on the preparedness and response phase.

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Figure 4 Phases of disaster management activities

The first phase is usually considered to be planning/preparedness and refers to actions taken to lessen the impact of predicted incidents. Preparedness and planning is a continuous process that should be seen as a pro-active preparation for an “all hazards” approach to disaster management, with exercises to train for the operational response to a disaster. A disaster plan is established providing guidelines for activation of the disaster management system and allocation of available resources required in response to the incident[3].

The second phase, response, refers to the rapid emergency actions taken in response to an incident, and management of its immediate consequences. This includes the actions of a number of response agencies (e.g. rescue service, police and EMS). Once a MI is declared, action plans are activated where action cards define and formulate to whom various areas of responsibility belong. An optimal response to a disaster situation requires efficient allocation of resources if one is to save lives and is mainly founded on effective disaster planning and preparedness. The fundamental principle of disaster management is to reduce morbidity and mortality [17].

The recovery phase is the process of the restoration of all aspects concerning the disaster’s impact on the community affected. During this phase, evaluation processes commence where data on performance are collected and analysed together within the community affected. Experiences and lessons learned are documented and shared with other response agencies. This phase may last from months up to years [8].

The prevention/mitigation phase involves activities to hinder, prevent or lessen the severity and impact of a potential disaster. Substantial progress has been made regarding disaster management in recent decades with greater emphasis on mitigation trough the development of disaster-resilience at national and community levels [3]. A comprehensive approach to reducing disaster risk was adopted in a worldwide framework for action in 2005 that also emphasised the importance of resilience in hospitals [66, 67].

2.1.5 **Disaster preparedness and medical response**

Even if there are structural and organisational variations in emergency preparedness and response systems between nations and communities the basic concepts and principles are the same [3, 17, 57, 68]. It is of extra value if a system can be applied broadly [23]. Preparedness measures also aim to improve disaster response operations through education, training, exercises and evaluation. Education and training principles (basic management principles) should in fact be the same regardless of whether the incident is a major accidents or an incident of greater magnitude [23, 49, 63, 69]. These command structures are commonly established through legislation or doctrines incorporated in disaster plans, they should be easy to follow and understand, and as far as possible adhere to the doctrine of daily routine [70]. However, a majority of health-care providers have limited training or experience in disaster management [12, 63, 71] Furthermore, they cannot be expected to learn the functions of disaster management at the scene of an incident [17, 69]. To date, there has been limited research aimed at identifying and validating indicators for measuring disaster medical response and the management process at each level of the response, that could have an impact on outcome, in terms of morbidity and mortality (output data) [33, 41, 50, 72].

2.1.5.1 Preparedness

A community that is prepared should focus on an “all hazards” and “all agencies” approach to the management of major incidents. Even though hazards may seem unique, solutions to them can be generalised [63, 69]. General disaster preparedness, including planning and response, is based on existing (healthcare) organisations, that must be prepared to face unexpected situations trough redistribution of resources and changes in work procedures [27]. Mobilisation, organisation and allocation of health-care resources requires established plans, a management system and organizations that are prepared [23]. Disaster plans must be simple,” well-rehearsed", and based on normal procedures familiar to the organisation, according to the “doctrine of daily routine” and with a terminology adopted by their own community or nation [17, 23, 70, 73]. However, written disaster plans do not guarantee preparedness. Written plans are documents that must be continuously revised and updated to meet the ever changing panorama of incidents. It is the process of planning itself that creates disaster preparedness. [23].

2.1.5.2 Medical response: notification, medical command and control and coordination

The immediate response to major incidents, from a health care perspective comprises notification, command and control, coordination and decision-making. Successful response to a MI depends, to a large extent, on the effective implementation of essential activities that provide for an immediate and coordinated effort of resources’ available [63, 74]. Emergency medical systems must follow pre-defined response plans. EMS is a national concern that provides for out-of-hospital emergency medical care and transport to definitive care [75]. This also emphasises the fact that disaster response must be carried out in a systematic and simple way. This requires knowledge, and repeated training and exercise [17, 76].

The emergency medical communication centre (EMCC) including the emergency medical dispatchers (EMD) are a part of the EMS and play an important role in initial notification and should be available all hours of the day [77]. However, EMCC organization varies greatly between nations and even within communities [61]. The initial action taken by the EMD is vital to the EMCC, and their contribution to the combined efforts of all responding EMS. During the disaster medical response it is of the utmost importance that the incident command structure is operative as soon as possible in order to manage the medical response. There must be no delay in alerting management at different levels [63, 78]. When an MI strikes the initial responsibility for responding and organisation of resources often resides at the regional level and at the local level. But, requirements can sometimes increase rapidly so that it is necessary to increase the response to the national level [27].

Medical command and control (management system): many of the current management principles apply to western cultures such as the Incident Command System (ICS) frequently used in the U.S [79] and the British Major Incident Medical Management and Support (MIMMS) [68] used in Europe, Australia and other countries [80] . The management and support principles in these systems help to effectuate a rapid and coordinated response to specific situations by having standardied actions for management functions. Its focus is on clear communication and accountability. Brendon [81] underlines the importance of understanding the impact of culture on management principles when adapting management systems in different countries.

Clearly defined management levels are essential as guidelines for disaster preparedness when EMS and health care facilities have to cope with a unexpected high casualty load from the early response [49]. Each level of command and control has specific responsibilities, activities, function titles and standardised coordination and communication procedures [63]. The organisational structure should be able to adapt to any situation by expanding or scaling down when necessary.

On-scene management (pre-hospital): during a major incident EMS are on the frontline of the medical response. When a MI is declared, the EMS have specified duties to perform. However, ambulance staff has varying degrees of experience of working at the site of a major incident. In European countries, on-scene organisational principles are similar probably because many courses they share have the same structure and content regarding medical management and support. Despite the variety of organisations it is of utmost importance that all medical personnel are familiar with their own organisation [17].

The responsibility of the commander at the scene of the incident is to initiate necessary patient-related measures by ensuring order and structure. This involves allocating recourses, setting limits, delegating specific tasks, and to giving support to those involved [17]. Management procedures must be organised rapidly and in the correct order. Decisions taken have an impact on subsequent morbidity and mortality, which is why a good incident management system is critical [82]. These tasks may be memorized using the mnemonic CSCATTT (Figure 5) according to the MIMMS concept [68].

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Figure 5 CSCATTT framework

Hospital management: crucial to hospital disaster preparedness is the ability to rapidly expand beyond normal capacity in order to meet a sudden influx of patients [44]. This mandates advance planning and preparedness. In the case of a MI, the first unit likely to reach the limit of its capacity is the emergency department, often followed by the radiology, operating theatre and intensive care units. Patient logistics in such a situation constitutes a significant workload challenge for the personnel. It is very important that all involved are fully aware of their own role, as well those of others [48]. A disaster plan describes the procedures for each function involved in a response, generally; who will do what, when, how, and where and also in which order.

Efforts to improve hospital disaster preparedness have recently started to focus on surge capacity, defined by the American College of Emergency Physicians as the "healthcare system's ability to manage a sudden or rapidly progressive influx of patients within the currently available resources at a given point in time" [83]. Surge capacity refers to the hospitals ability to respond to an incident to meet an increased demand for medical care, whereas surge capability addresses specialised medical resources (e.g. burn management) that are likely to be required. Surge capacity is influenced by three crucial elements; staff, stuff (supplies and equipment) and structure [83]. Although the absolute number of critically ill or injured patients have a large impact Aylwin et al. [82] after the July 2005 bombings in London points out that an even more critical factor is the initial period over which those patients arrives at the hospital.

Coordination and communication: response-coordination is a great challenge depending on the nation`s or community`s jurisdictional disaster preparedness and management systems and principles [11, 27, 84]. The scene of a incident involving severely injured patients is a complex matter demanding collaboration and coordination between various agencies [85]. Responding agencies need to coordinate and cooperate concerning immediate resource requirements. Whereas resources may be overwhelmed as a result of a major incident, lack of coordination is said to be more common than resource shortages in smaller incidents [86]. Coordination in general, as regards response, is often performed through cooperation (liaison) . It has been stated, however, that lack of coordination and communication between agencies, institutions and individuals is a frequent problem in the DMR [69, 87, 88].

The importance of communication and timely information from officers in the field is the subject in several studies [27, 50, 63, 89]. Communication failures may occur for a range of reasons. An important issue is to avoid breakdowns in communication [63] as well as misunderstandings related to hierarchy that contribute to communications difficulties [89]. Appropriate communication systems are vital such as data reporting systems. However, collecting and transmitting information is often described as difficult since information and updates about resources and incoming patients are insufficient or lacking [27, 50]. An effective medical response demands that information be shared and fed back to the commander [89].

2.1.6 Decision-making

The cornerstone of DMR is decision-making at all levels of management, dealing with allocation of medical resources, patient management and mobilisation of personnel. All decisions are based on available information (input data), and in the case of imbalance of resources decisions must be taken very rapidly. Factors such as context, risks, insecurity and stress, are variables that affect the ability to make decisions.

Decision- making is frequently described as an activity with a large degree of risk-taking [90]. Cognitive field research methods are used to gain insights into the strategies people use in decision-making and how this is coordinated and communicated within the organisation. This knowledge has also been used to develop decision support systems [91-93].

In command and control situations contextual factors such as time pressure, continually changing conditions and elements of uncertainty ought to be understood in the light of capability person`s ability to handle difficult tasks under stressful conditions [91]. Knowledge in management, and above all experience and recognition gained from studying different incidents have been shown to have a major impact on the decision-making process [91, 94].

Research on decision-making in clinical practice is mainly based on analytical (traditional) and non-analytical (naturalistic) decision-making models [90] . However, traditional analytical strategies are not considered very useful in real life decision-making. More suitable is the naturalistic approach (cognitive field research) developed from research on how experienced professionals in command and control (pilots, military officers, firemen and medical personnel) use their experiences to make decisions in complex and dynamic real life settings. Naturalistic decision-making differs from the traditional by using a blend of analytic and intuitive approaches in decision- making [91, 92, 94]. Experienced professionals put great trust in their experience and intuition.

Little research, however, has addressed the nature of decision-making in prehospital care settings. The first ambulance crew on the scene of an incident makes triage decisions. Arbon et al. [95] underline that each stage in the decision process is affected by making crucial choices and using experience. According to Fry et al. [96] the decision process is a cognitive process that includes, clinical reasoning, negotiation and judgment pattern recognition. Although, it is essential to describe factors that underline decision-making it must also be possible to document all information upon which s decision is based and the possible consequences of that decision.

2.1.7 Medical documentation

Inadequate information and uncertain factors contributes to making the decision making more complex in medical response. Insufficient information can lead to misunderstandings, hampered data gathering and problems in communication [94]
Within any health -care system there is a legal obligation to document decisions made and treatments given by medical staff outside hospitals. To be able to do this, you have to have a balance between the ambition to rapidly evacuate the patient from scene of accident and the obligation to provide up-to-date documentation. Medication given must always be documented and certain data are essential for reassessment of triage decisions [17]. Waage at al. [97] describes inadequate documentation and emphasises that this is probably the case when there are many severely injured patients and that there is a need for simply triage tags for easy reporting. Others have also highlighted this [27, 50].

2.1.8 Leadership

Major incident is a complex matter when the combined competence of several agencies is put into practice in the response to a MI. All agencies have to follow their own leadership structure, laws and regulations and this puts high demands on the medical management system and leadership. The only way to reach the outcome desired is by preparedness and exercises [98, 99].Gunnarssons et al. [94] found that ambulance nurses perceive the role of leadership as difficult because of the many hard decisions that have to be made. For ambulance personnel first at the scene of a MI the role of operative leadership is a central function. The leadership role is demanding and requires education and training [94, 100]. Leadership at the scene requires authority in order to direct the rescue service, police and ambulances crew on how patient-related work shall be prioritised [14, 100]. If leadership fails, the rescue workers and medical personnel won't receive relevant information or are assigned irrelevant duties, with the result that outcome (mortality and morbidity) suffers [49, 101].

Ambulance and hospital personnel have varied skills when it comes to leadership. Those expected to have leadership role at a MI need regularly training to develop these skills. In general collaborating agencies such as the rescue service, police and the military all have a well-established operative command structure [100] and operative leadership is a natural component of their daily work which is not the case in the health care sector [17].

Gunnarsson et al. [94] highlights the importance of that personnel involved in MIs knows who is in command and understands the leadership and command structure. Carne et al. [89] points out the importance of ensuring leadership and the role clarity in critical emergency medicine settings. They postulate that leadership is best performed in a co-determination manner but in time critical situations a more authoritarian approach is requered. Leadership structures such as command and control work effectively in MI management situations since decisions must be made quickly without or with little time for discussion [101]. Part of the leadership role includes recognising personnel affected by stress and the provision to direct those in need to peer support or/and counseling services [89, 100].

Coordination and collaborative response activities are needed, both within and between the agencies involved during the response phase. Auf der Heide [102] pointed out that the key to effective collaboration appears to be the interaction and coordination of response agencies before a disaster strikes. One of the best ways to become familiar with the functions of other agencies in disaster response is by collaboration exercises, interactive simulation (table top) or training exercises [103, 104].

Furthermore, Carne et al. [89] underlines the fact that team members should have an active role where each individual must share an understanding of the incidents' management goal and be clear on their own task work responsibilities. In these situations is it crucial to feed information back to the leader, support each other as needed, and declare the need for corrective action when indicated. The use of action cards has been shown to make a significant improvement regarding the successful completion of necessary tasks [17, 89]. Other researchers have described specialist ambulance nurses interpretation for leadership as a demanding responsibility. A sense of security emerged if they worked with competent staff and had earlier experience from decision making and care giving in emergency situations [14].

In a literature review on leadership aspects important for management and collaboration of accidents and crises Danielsson et al. [105] points out areas where more research is needed. Carne et al. [89] underline that the performance of complex tasks, that must be organized rapidly, deteriorates by factors to do with the self (fatigue, inexperience, lack of knowledge) and environmental factors (lack of resources, equipment failure) [89]. Aitken et al. [100] found in a survey that poor leadership was a major challenge that members in disaster medical assistance team were confronted with. The study also identified a need for a command structure between agencies as well as internationally and point out leadership as a learned skill.

2.1.9 Triage

Triage is the rapid assessment of patients and assignation of the most appropriate level of medical care and treatment, given the limited resources at hand [3]. This decision process has its roots in the history of military medicine especially during the Napoleon wars. The word triage is derived from the French verb "trier", which means to sort or select. Triage is carried out systematically in order to deal out treatment efficiently, taking into consideration the severity of the patient's condition, available resources, and several other factors governing effective care. Several triage systems exist around the world, each of them using different triage tools [27, 48, 106, 107].

As decision-making is the cornerstone of disaster management, triage is the link between organisational and medical decision-making. Despite the fact that triage decisions per se are always performed, there are few reports on how these decisions are communicated within the system i.e. the actual use of triage tags in real incidents [108].

Suserud [85] divides pre-hospital emergency care into two main areas. The first involves the day-to-day caring and transport of sick patients or patients with minor injuries. The second involves resuscitation-type activities at incident and disaster sites. When divided in this way it is important to distinguish between field and disaster triage and other forms of triage e.g. ED triage or inpatient (ICU), and between triage systems with or without resource limitations.

There are three main ways to perform triage in the pre-hospital setting. Triage can be based on anatomical or physiological data or a combination of both. Anatomical triage is based on visible and observed injuries. Decisions based on physiological parameters have two components sieve (primary) and sort (secondary) to categorise patients. However, the majority of these systems use triage sieve at the incident site to identify severely injured patients for evacuation and transport to definitive care (e.g. Triage Sieve, START, Care Flight and Sacco triage). Triage sieve is algorithm-based and uses ability to walk, respiratory rate and pulse to classify patients into categories. Triage sort is often paired with triage sieve and uses motor response (Glasgow Coma Scale), blood pressure and respiratory rate in the same way as the Revised Trauma

Score (RTS). Triage sort generates a triage score that reflects a patient's physiological state, and the urgency of care and transportation required. The reproducibility and applicability of RTS to a wide range of trauma patients has made it attractive in the pre-hospital setting and for disaster triage [109, 110].

There are different triage systems, each with limited validation [86, 95, 111-113]. No triage system has been shown to be more accurate than any other in the context of incident management, resource allocation or patient outcome [109]. In simulation settings Lennquist Montán et al. [114] showed significantly better calculated outcome with anatomical triage compared to physiological triage when performed by medical staff. Rehn et al. [5] presented results that indicate that triage based on vital signs and anatomic injury requires a high level of medical competence.

Triage is done using a device called the triage tag. Colour-coded triage tags are attached to each patient to indicate the patients' condition and to communicate the priority of treatment and transport. Moreover these tags also have a place to write information about the condition and vital signs of the patient thereby serving as a sort of patient notes. Triage is a dynamic process, as the patient's condition can change very rapidly[109, 110]. The fewer resources that are available, the more important triage and the tagging of patients are. Triage tags are included in the ambulances and medical teams' equipment and, according to guidelines, should be used in major accidents and disasters. Although, triage concepts are presented in textbooks worldwide and regularly practiced in training and education courses, there are few reports providing data from real life experience [22, 70, 95, 108].

Sweden has a relatively low incidence of severe trauma cases. This, according to Abelson et al. [14] contributes to the difficulty in maintaining and increasing skills in rapid assessment of severely injured patients at the scene of a major incident. Triage assessment of vital signs is a prerequisite if one is to rapidly identify patients requiring immediate attention. Long periods without practice of specific knowledge and performance skills, is emphasised in the literature as a cause of vulnerability in emergency response and triage accuracy [23, 46]. An analysis of on-the-scene triage sieve used in the terrorist bombings in London 2005 indicated greater accuracy when performed by experienced EMS personnel compared to medically trained bystanders [82]. Risavi et al. [22] in a study on skill retention among pre-hospital personnel showed that skill deterioration is associated with infrequent use of triage systems. Failure in the triage process at a MI is related to little or no documentation, lack of tags or tags not being used at all [1, 27, 85, 109, 115].

The accuracy of triage is essential in medical response, and important for the overall understanding of the triage decision process since it has such impact on patient outcome. There are two sorts of inaccurate triage. The first is classified as under-triage which is when a critically injured patient, with life threatening problems, is classified as non-critical and thus not transported to hospital in time. Under-triage may lead to unfavourable consequences or preventable death. The other is classified as over-triage when non-critically injured patients are triaged as severely injured when this is not the case. These are quickly transported to facilities that provide the highest level of care, thereby increasing the risk of denying critically injured patients immediate care [5]. In the routine care of trauma patients, over-triage, so as to minimise under-triage is generally accepted [116]. However, in major incidents with limited or strained resources both over- and under-triage lead to unnecessary deaths [5, 46, 63]. The American College of Surgeons Committee on Trauma (ACS-COT) have defined an under-triage rate of 5 % as acceptable and associated with an over-triage rate of 25%-50 % [5]. Minimising both under- and over-triage requires extensive training of EMS personnel [63] and ongoing secondary triage at every stage. A study that used data from 12 terrorist bombing incidents [46] shows a direct relationship between over-triage rate and critical mortality rate. Hence, disaster triage and triage accuracy are essential in disaster management [63].

2.1.9.1 Field triage

Field triage is a decision process based on guidelines that apply to routine triage of injured patients in usual pre-hospital settings [5]. EMS personnel classify patients by measuring vital signs and assessing the level of consciousness. Field triage is not designed to be a disaster triage tool. However, confusions may exist as to whether guidelines apply to routine day-to-day triage of injured patients or to disaster triage [117]. The goal of field triage is to ensure that critically injured patients are transported to a health-care facility that provides the appropriate level of care [88, 117]. Field triage is essential in order to identify trauma patients that require trauma team resuscitation at regional trauma centres [5]. For critically injured patients, trauma centres have been shown to have better results [118], and their use should be optimised [88].

2.1.9.2 Disaster triage

Disaster triage is a decision process that is outside the “routine” experience of EMS personnel and concerns mass casualty triage [46]. Disaster triage is usually divided into three phases; *treatment*, *transport* and definitive *hospital care*. Compared to field triage, disaster triage requires an entirely different approach to assessment and care, due to restriction of medical resources. In disaster triage, focus changes from routine management i.e. doing the best for each patient to doing the best possible for the greatest number of patients in order to optimise incident outcome [27, 46, 82]. The challenge is to identify critically injured patients that may be saved despite limited resources [27, 46, 63, 76]. Disaster triage is the allocation of limited medical resources in order to optimise patient outcome [109].

Disaster settings also place high demands on EMS personnel due to the incidents complexity and differences in individual skills in triage [22, 46, 82]. Disaster triage can only be as effective as the degree of EMS personnel’s knowledge and training in the principles of mass casualty management [63]. Furthermore, EMS personnel face ethical challenges (utilitarian approach) when resources are limited [119].

Written documentation of triage decisions is essential for systematic reassessment, re-prioritisation and distribution patients to the correct level of care. Frykberg [46] points out the chaotic environment influences on triage decisions increasing the risk of omissions of treatment and losing track of patients. Zoraster et al. [88] described chaos and confusions at the scene of a train crash making it difficult to keep track of patients. Furthermore, the accuracy of triage decisions and their impact on patient outcome are key elements in post-event analysis from which essential lessons may be learned that leads to improved decision-making at future MIs [46].

2.1.9.3 Treatment

Disaster triage is of utmost importance in major incidents where medical resources are inadequate. Decisions of critical importance for patient outcome have to be made under time pressure and this requires experience of assessment and decisions-making without delay [49]. The EMS provides the treatment necessary to stabilise the patient prior to transport to an appropriate health-care facility. It is important to match patients with health-care facilities that have suitable resources to provide the care necessary [88]. The challenge is to recognise critically injured patients that require immediate care, from patients who are not critically injured.

2.1.9.4 Transport

In order to use triage effectively, the underlying evacuation logistics of an EMS must be in place in order evacuate patients to the most appropriate health-care facility [99]. Rehn et al. [120] indicates that a well organized transportation chain needs access to standardised equipment to optimise evacuation efficiency. Evacuation focuses on rapid access to definitive treatment to improve the medical care of critical injuries, and to provide specialised care where necessary [63].

Frykberg [46] describes the orderly distribution of patients to several hospitals in order to avoid overwhelming any single one otherwise the geographically closest hospital may become overloaded with injured patients, impairing efficient management. Maldistribution of patients during a disaster is frequently reported [27, 88, 121]. Disproportionate distribution can increase even more when survivors make the decisions to transport injured patients to the hospital closet to the scene [27].
International disaster experience has revealed this so-called “self-presenter” phenomenon where many patients from a disaster refer themselves without the benefit of pre-hospital triage, treatment or EMS transport [38]. O’Neil [11] states that the time interval from exposure and injury to definitive care is one of the most important factors that can influence patient outcome after a MI. This is in accordance with Frykberg findings [98]. To avoid maldistribution and to achieve the best outcomes (avoidable mortality and morbidity) rapid triage at the scene and a coordinated evacuation response from all management levels involved (local and

regional) are essential [11]. The use of regular disaster exercises is one way to test such coordination [49].

Delays certainly have a price and some reports shows that incidents sites are usually cleared of injured patients within 1-3 hours [1, 32, 88], but the hospitals efforts last substantially longer. However, most MCIs have a relatively low percentage of critically injured patients [82, 115, 122].

2.1.9.5 Emergency department

Effective and accurate disaster triage at the scene is necessary, and if not performed well this will tend to overwhelm hospitals resources immediately [98]. In these situations, as well as in daily ED triage, the goal is to separate patients in need of immediate attention and those that can wait for treatment without increasing their risk of mortality or morbidity [3]. A more detailed triage and prioritisation process can be carried out at the ED. However, lack of triage tags and documentation can make it hard to determine what treatments patients have already received upon arrival at the ED [123].

The hospital is a vital part of the DMR and is involved from the start. Hospitals have to respond rapidly by creating surge capacity (arranging available resources to cope with a surge of patients) [83]. To facilitate a smooth transfer, it is important to ensure that the receiving health-care facility and personnel have been contacted directly by the EMCC or duty officer. The hospital ED is a complex setting with high workload that is highly stressful for the staff [124]. Existing disaster plans help the ED staff to rapidly allocate available resources, triage patients, provide lifesaving medical care, and to coordinate contacts and transportation to x-ray, the operating theatres and the intensive care units [125, 126]. A heavy casualty load can affect the quality of trauma care and puts a high demand on the leadership role that surgeons must play in the resuscitation of the most critically injured [46]. Standard major incident procedure is to spread out the transport of injured patients to avoid overloading individual hospitals.

Brandt et al. [124] highlights the ED’s ability to rapidly expand the capacity to meet a sudden surge created by the MCI. This requires rapid response, initial decision-making, initial management, triage and security. Triage and security processes in the ED have been pointed out as being vital to maintaining control during the surge and consequent flow of patients through the hospital system.

2.2 ISSUES THAT NEEDS FURTHER ATTENTION

2.2.1 Effectiveness of today´s tool-improvement

Organisations within the emergency management system use digital or analogue communication systems which enable direct communication between and within those involved. In the health-care system, communications concerns overall logistic issues as well as direct patient- related information such as status, where the patients is located (tracking) and triage. Patient tracking and rapid triage information transmission is a demanding challenge in pre-hospital and hospital management. Currently EMS providers rely on paper based triage tags to record patient data, and communication is mostly verbal.

Written triage documentation in the field is sparse and sometimes lacking [22, 70, 95]. The assessments of actual performance of triage and care is difficult since this is a balance between efficient life saving treatment and documentation [17]. Ways to document actions in the field must be improved so that retrospective analyses of triage decisions and the quality and accuracy of treatment can be carried out by researchers [123].

2.2.1.1 Technical support system

Real-time information is critical for medical commanders who must coordinate up-to-date information on the number of patients and their needs with available resources, and also the capacity of the receiving health-care facilities [127]. There is an ongoing development of information technology that is likely to improve the quality of clinical patient information and tracking in the disaster settings [127-129]. New techniques for automatically spreading information among all personnel involved save time and resources, enhance situational awareness, patient care and improve outcome [127]. Sutherland points out about the complexity of modern healthcare that this has outrun the capabilities of manual and paper-based operations and that there is difficulty in adopting new technologies [130].

The radio frequency identification (RFID) technology is in wide use in the logistic operations of industrial and commercial enterprises. However, in the health care sector the technology is still rather underdeveloped [128] and relatively little work has been performed on computer systems to facilitate emergency response [131]. The technical support system is now being integrated into hospital systems to provide information on the flow of patients, staff, the location of medical equipment, and supplies [130-132]. This techniques application takes advantage of radio-frequency electromagnetic fields for storing and retrieving data. In recent years various concepts for extending triage tags with bar codes, and RFID chips have been presented [133, 134]. Special devices called RFID tags and scanners connected to a computer system are mandatory for this system[128]. RFID tags can provide real-time patient information and location within the health-care chain [135].

Jokela et al. [134] describes an application system to simplify the disaster triage process based on commercial mobile networks and mobile phones with integrated RFID technology. The system was evaluated in disaster exercises to study the systems suitability in mass casualty situations. Instead of manually update triage information the information was stored in an RFID tag attached to the patient. The technique allowed EMS personnel to spend more time on patient care instead of patient records. The RFID system was also shown to improve the situational awareness of medical commanders. Ingrassia et al. [136] found similar improvements when comparing the RFID system with a manually recorded system in a disaster exercise setting. Fry et.al [131] describe a software–hardware system designed to enhance management of resources at a hospital during a major incident. They theorize that real-time location of medical 'assets' using RFID tags and a visual dashboard would be useful in responding to MIs.

2.2.1.2 Situational awareness

The term situational awareness is frequently used in the context of DMR and can be described as the comprehension of situation-specific factors that have an effect on performance in complex tasks to facilitate effective, real-time decisions during rapidly evolving events [131]. The medical commander must know what resources are available at any given time (situational awareness), and understand the need for allocation of resources and where and when they will do most good. This further emphasises the importance of the number of patients and their triage category on situational awareness [29]. With real-time information, hospitals can plan their response more efficiently on the basis of accurate estimates of the number of patients and their conditions [27, 46]. In existing Incident Command Systems, situational awareness is often achieved through manually paper-based tracking systems and radio communications.

2.2.2 **Training methodology in Major Incidents**

Disaster exercises and simulations are routinely used throughout the world serving as a major teaching and training tool [21]. Exercises that simulate incidents are often recommended as a good means to improve disaster preparedness and to evaluate the systems' capabilities and capacity [137]. It is essential to point out, however, that real incidents are often quite different from exercise and simulation settings. Appropriate teaching must be both theoretical and practical, and the use of simulation models gives the opportunity to integrate theory and practice [23, 48] . The importance of being "trained", rather than being "educated" in disaster management has often been emphasised. Macnaughton [138] underlines the importance of being aware of the differences between education and training in medical education. Education is a process having a broad perspective, as opposed to the narrow focus of training. In this context, known from the literature disaster medicine education has a tendency to be neglected [71, 139, 140]. As the educational theorist Peters says *"to be educated is not to have arrived; it is to travel with a different view"* [141]. Furthermore, the infrequency of major incidents necessitates the regular training of those heavily involved, to refresh their ability to act in a simple and systematic way [22].This requires careful planning for the re-training of complex tasks [18].

A progressive approach for managing incidents ensures that loss of life and property is reduced in a MI response. There are only two ways to assess how well this works; by facing a real incident or through exercises. However, skills in medical response cannot be trained in real incidents [17] and several studies indicates that current evidence on the effectiveness of preparedness training is limited [9, 19]. Hence, there is a clear need for the development and evaluation of training and education methodology. To achieve knowledge and skills in MIs response educational methods based on validated learning models and realistic simulation models for interactive training is needed [17].

The major learning theories currently being used by education practitioners are based on Kolb´s model of adult learning (Figure 5) [24]. This perspective of “experiential” learning has its origin in the work of Dewey, Lewin and Piaget [142]. Kolb´s model shows learning as dialectic process integrating: experiences and concepts, observations and action, with learning styles: diverging, assimilating, converging and accommodating. Concrete experience and abstract thinking is how we retain information, while reflection and active experimentation stands for how we use it (Figure 6) [24]. Experiential learning is defined as *"the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience"* [24].

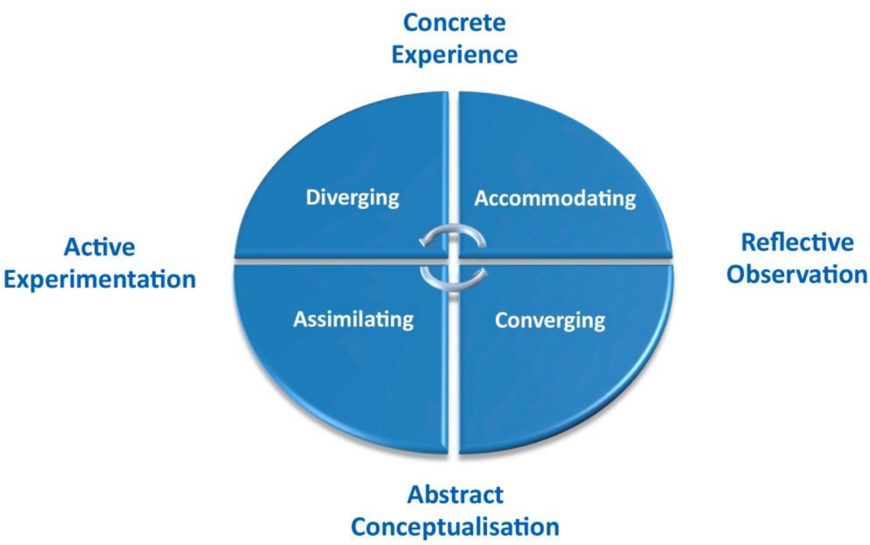

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Figure 6 The experiential learning cycle and basic learning styles (Kolb, 1984) [24]

Despite growing interest in education and training within this field validation of educational and training contents is sparse [17, 20, 143]. Furthermore, comparison between studies is problematic because of the variety in study subjects, design and interventions [9]. The same applies to the validation of training in public health preparedness. Potter et al. [144] made a search in a substantial number of peer-reviewed papers (n 163) on preparedness training and exposed notable gaps in the design and conduct of exercises. This indicates the limited usefulness of preparedness training if best practice not is achieved and recognised. Furthermore, in large organisations only a small number of personnel are involved in disaster exercises which leads to lack of experience for a large number of individuals [12, 63, 69, 71, 143]. Providing effective disaster preparedness training provides several challenges.

Hsu et al. [143] besides underlining the importance of identifying best practice and specific target audiences, they point out that the content that should be taught must also be defined. Furthermore Burstein [73] and Garner [70] discuss the need for "doctrine of daily routine", in the stressful situation of a major incident health care personnel do what they usually do. They also stress that regular exercises to maintain familiarity are essential and we live up to that expectation when we design disaster plan and exercises .The capability to work in different situations with various agencies places high demands on the knowledge and skills of the personnel involved [63]. Suserud [76] placed emphasis on how ambulance personnel experience their own actions in a MI, and showed that they experienced a discrepancy between how they had been trained and the reality they faced in a real MI. Lindblad et al. [145] underlines that efficient skills can only be achieved in the field and not theoretically.

The fact that experiential learning is an ongoing process indicates that all learning is re-learning. Thus realistic simulation training is an essential complement to maintain the accumulated experience gained from different situations, by raising awareness, and the application of experience in simulated scenarios [48]. One way to achieve this is the use of simulation models to test the various components of disaster medical response, e.g. notification, command and control, coordination and decision- making [17, 146]. There remains a substantial need for prospective systematic and validated evaluation tools to assess the performance of organisations and hospitals during exercises and simulations [12, 44]. So far the competence and effectiveness of EMS and hospital performances are seldom assessed in a way that allows results to be compared.

2.2.2.1 Models for Interactive Training

There are several ways that exercises can be designed and evaluated, from computer simulation [86, 147, 148], to more traditional disaster simulation [19], and to simulation models [149, 150].

Traditional table-top exercise (seminar exercise); is based on discussion, and used to train decision-making and the logistics of disaster response [19]. This is the simplest form of exercise with a low degree of interactivity. A chairman leads discussions with participants on particular subjects or scenarios to identify gaps in plans, protocols and procedures. This form of training is time-and cost-effective, and has less impact on daily operations than the more advanced forms of exercise [151].

Table-top exercise (simulation model); is experience-based with a high degree of interactivity by creating a virtual experience for the participants in which participants respond to and take appropriate action. The simulation system uses symbols to illustrate resources and injured patients on whiteboards, on tables or on computers. This form is considered to be more cost-effective then field exercises [17].

Functional exercise; is a simulated interactive exercise that tests the capability of one or more organisations to respond to a simulated incident without moving real people or equipment to an exercise site. This exercise strives for realism and focuses on coordination and management within or between various response agencies. This form is more resource consuming (personnel time) and expensive than table-top exercises, and may divert resources from other important needs that can disturb routine medical care [19].

Full-scale exercise; is a simulated major incident, as close to reality as possible. It involves all disaster response organizations; e.g. EMCC, ambulance, police and rescue services for testing the preparedness of the multidisciplinary emergency system and requires full deployment of equipment and personnel [76]. This form of operation-based exercises require representatives from all participating agencies in the design of the exercise, to assure that the scenarios are credible and logistically feasible to implement, requires extensive planning time, and is expensive to perform [16, 152] (the total costs for these exercises are seldom presented). This type of disaster exercise provides the opportunity for emergency services to practice disaster response in a complex realistic disaster scenario environment often using figurants acting as injured/shocked/uninjured patients [44]. This form of exercise is often criticised for lack of realism in terms of what is required of incident managers and responders, since management procedures are simplified and do not mirror realistic times and consumption of resources [17, 153].

Simulation system

In Sweden there are two pedagogic table-top simulation tools for interactive training in the field of disaster medicine and health-care; the Emergo Train System™ (ETS) and the Mass Casualty Simulation™ (MACSIM) system [17, 149]. Interactive Simulation for Emergency Exercises (ISEE) is a computerised interactive simulation system developed by an international group of disaster medicine experts [154]. This system, which resembles both MACSIM and ETS is not used on a regular basis in Sweden. Simulation systems have the advantage that they simulate the whole chain of events of the different components in medical organizations. These systems make it possible to train and evaluate decision-making incident coordination and command and control. The advantages of these systems is to let participants experience realistic human interaction in difficult situations [17].

These systems are based on a number of magnetic symbols (e.g. victims, in-hospital patients, specific staff and different kinds of resources) plotted on whiteboards. Participants can indicate triage and treatment, use of resources (e.g. available staff and equipment) and transport in realistic (real) times, thereby testing the capability to cooperate/interact and perform disaster management procedures in an accurate and efficient way. The key component in each system is the standardised victim bank/injury card which can be used for both table-top exercises and field exercises [17]. The ETS victim bank is based on a national consensus among traumatologists. All victims have predetermined medical requirements and belong to a certain injury category whit a predetermined outcome based on the Injury Severity Score (ISS) [117], if defined measures not are performed or performed too late. This allows patient outcome to be evaluated in a structured way [72, 155]. Until now research has seldom linked patient outcome to how a situation was managed[72].

2.3 EVALUATION AND QUALITY CONTROL

2.3.1 What the standard requires

The effectiveness of disaster exercises is difficult to determine as there are few objective data in the literature. Few reports include methodology used for validation of educational and exercise models e.g. pre-and post-test analysis or statistics showing progress [17, 19]. Several researchers have indicated the need for validated assessment methods performed in a genuinely scientific manner in order to measure the effectiveness of a disaster medicine response [21, 32, 42-44].

To be able to achieve this there is a need for standardisation and sets of goals (bench-marks) reflecting what is to be considered as good or less good performance. These processes and goals must be developed in a way that allows them to be systematically studied, analysed and provide the possibility to compare results and experiences [27, 30]. In most healthcare systems the use of quality indicators are mandatory for determining standards consistent with good clinical practice, and for measuring quality[156]. Indicators should be based on well-developed standards established and accepted by the organisation to ensure comparability and reproducibility. The challenge is to address the question of indicators even in the field of disaster medicine[50].

Indicators in health care are used for determining what is to be considered as good quality or practice. In principle there are three different kinds of indicators in the literature that describe the quality of care, performance/process, outcome and structure indicators. A process indicator describes activities or processes involved and how well they are performed, and usually associated with patient outcome. Outcome describes what is achieved e.g. states of health that follows care given. In disaster medical management the reduction in morbidity and mortality of disaster survivors is the most important outcome [12]. Outcome indicators in research so far are very seldom linked to decisions made by managements groups in a validated way [72]. All disaster medical response activities that influence patient outcome must be one of the most important areas that needs to be identified [50]. Structure indicators are quantitative measures reflecting organisational characteristics and availability of resources. For example, how the system is alerted, and the number of ambulances involved in medical response at a MI. From the quality improvement perspective it is important to study the link between process, outcomes and structure [156, 157].

The use of measurable quality indicators to compare the level of performance with predetermined goals and objectives has been addressed in previous studies [33, 40, 158]. In these studies the quality indicators represent measure desired performance variables (times and content) in the management of MIs. The indicators selected were derived from a national concept and process modeling/or the opinion of an expert panel, conducted by the National Board of Health and Welfare in Sweden[56]. In this process experts, with considerable knowledge of the emergency preparedness system, defined important steps that take place during a MI. Idvall et al. [157] describes this as ‘the key to good quality indicators’ and the only certain way of knowing what is good or less good is by comparing measured performance against desired standards.

2.3.2 Indicators in relation to performance

Measurable performance indicators have been used in national teaching and training programmes for the evaluation of performance and effectiveness of disaster management training together with simulation techniques [31, 33, 72, 149]. Previous studies have also shown that relating indicators to performance can be useful in real incidents as a tool for quality control of management at the regional level [159].
An indicator can provide information about a specific issue, while a set of indicators provides information on a complex phenomenon (e.g. quality of disaster management) that is otherwise not so easily captured. They are meant to provide a quantitative basis for evaluating, monitoring and improving disaster management. [156].

There is a request for standardised and structured reporting of disaster medical response in MIs in order to make data available for evaluation, quality control, scientific analysis and development [10, 26, 30, 160]. The development of a standard template for registration of essential data from MIs and disasters can be achieved using various methods. Some published reports have used an international panel of researchers as informants, while others have been largely based on personal expert knowledge and experience [50, 161, 162].

Recording and analysis of data lead to significant understanding of the impact of processes involved. Nilsson et al. [159] found that performance indicators of regional medical response were feasible as a quality control tool after a retrospective observational study on 130 MIs. Data were collected from the files of two county councils in Sweden where the national medical incident command and control system had been fully implemented. Of 130 major incidents 36 were excluded due to insufficient documentation. The authors suggest that indicators that directly or indirectly involve patients can be applied in MIs, and that these could be a qualitative measure in regional and national follow-up systems [159]. However, there are now systems available for recording real-time data based on international consensus [50].

2.3.3 Sharing scientific knowledge

There is a significant multidisciplinary body of theoretical and research literature in the field of disaster medicine sharing performance and experience, generally termed lessons learned (LL). Lessons learned presented in after actions reports or evaluation reports are often recognized as key element for future planning despite their highly variable quality and limited utility. Furthermore, few studies provide a definition of the LL when they present or explore the concept of LL. When searching the literature a definition used by the American, European, and Japanese Space agencies is frequently used: *"A lesson learned is a knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. Successes are also considered sources of lessons learned. A lesson must be significant in that it has a real or assumed impact on operations; valid in that is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result"* [163].

Attention paid to LL by evaluators and different organisations has increased over recent decades. Patton [164] observed that evaluation has moved from merely generating findings to generating knowledge. In military medicine the modern term for LL rather refers to knowledge management and best practices in order to improve planning [165]. Best Practices, which comprise principles of effectiveness to guide practice, have become the most coveted form of knowledge. Providing there is reasonable evidence to support such a statement in terms of both internal and external validity criteria. Patton describes three purposes for evaluation: accountability, generating knowledge and programme development [164].

Evaluating the impact of education and training on performance in exercises or real incidents is an essential component in maintaining or improving the quality of emergency preparedness. It is important to see evaluation as an integral part of education, training and exercises[17]. The evaluation function has an important role to play as a central knowledge provider. Evaluation can help identify areas for improvement and ultimately help to achieve goals more efficiently [144]. Lessons learned were originally conceived of as tips, checklists or guidelines based on what went right or wrong in a particular situation. In military medicine LL process is often described as a closed loop consisting of Observe, Orient, Decide and Act [165]. Lesson learned from evaluation is knowledge or understanding gained by experience whereby knowledge is created through the transformation of experience (Figure 5) [24]. The sharing of information is important to everyone involved in disaster response, as own observations may be relevant to others [166].

It is common to present lessons learned after an incident [69]. Often these lessons are related to some of the most important functions of disaster management in areas of command, communication and resource allocation [153]. Despite the fact that in the past LL from major incidents have resulted in many improvements, shortcomings still exist [159]. Jufferman et al. [6] studied five national disaster responses and noted that many mistakes were repeated despite changes in protocols, legislation and organisations.

Koenig [3] and Donahue et al. [153] argue that the term “lessons learned” as a misnomer should be used with caution. Koenig [3] and Patton [164] claim that the term LL is more suitable to describe an individual who learns from personal experience. Koenig [3] proposes that scientific findings should be used instead of LL to form the basis for the continuously expansion of academic knowledge in disaster medicine. Organizations need sustainable knowledge not merely individual observations. According to Patton [164] one challenges facing future evaluation processes is to be more strict in the definition of the terms LL and best practices. This involves the analysis of findings from different studies to formulate generalized conclusion about effectiveness that can form a scientific basis for the profession. Having knowledge about performance effectiveness allows evaluators to provide guidance in the development of new policies, and strategies for implementation. This may be considered more as research then evaluation, but such research according to Patton is ultimately evaluation in nature and important for the profession[164].

2.4 RATIONALE FOR THE THESIS

Disaster medical response is a complex phase in disaster management where shortcomings may have negative consequences for the outcome (mortality and morbidity). Exercises that simulate incidents are used to improve disaster preparedness and to evaluate the systems capabilities and capacity. The literature shows that the available evidence is limited as to whether training interventions are effective in improving response in the disaster situation. To achieve knowledge and skills in medical response there is a request for educational methods based on good learning models and standardised evaluation methods. So far the competence and effectiveness of EMS and hospital performances are seldom assessed in a way that allows results to be compared.

Disaster exercises and simulations have been used since a long time and can support experimental research on disaster management. Research in the area should be focused on the implementation and the effectiveness of the intervention on processes and outcome. There is a need for elaborating with a number of different measurable indicators. One advantage of the use of measurable indicators is that they can be used throughout the disaster medicine “chain”, from education, training and exercises as well as real incidents.

A limitation in research studies on disaster medical management is the lack of a common vocabulary and the lack of standards for collecting and reporting data. If we are not using the same vocabulary it is difficult to analyse data and compare results. The availability of such data would enable researchers, educators and evaluators to study different aspects of the disaster medical response to improve the national and international consensus on knowledge and practice in medical response. Furthermore, the challenge for the future in disaster medical response is not only to validate triage systems there is also a need to increase real-time information (situational awareness) so that health care facilities can respond effectively. In order to develop best practice and increase our scientific knowledge, medical response needs to be further explored.

3 OVERALL AIMS

The overall aim of this thesis was to increase our knowledge of the impact of quantitative evaluation of medical response in disaster preparedness with special reference to full-scale exercises.

3.1 SPECIFIC AIMS

This was encompassed in the specific aims of the five studies.

I. To increase the ability to learn from the results of full-scale exercises by applying performance indicators at two levels of command and control.

II. To demonstrate the feasibility of using a combination of performance and outcome indicators so that results can be compared in standardized full-scale exercises (FSE).

III. To identify, from a Swedish perspective, key indicators essential for initial disaster medical response (DMR) registration.

IV. To explore the attitudes towards and experiences of ambulance personnel regarding the practice of triage tagging in the day-to-day practice of trauma as well as in major incidents.

V. To increase our knowledge of the applicability of a technical support system and its potential to provide real-time, overall situation awareness for those overseeing the medical management of the operation.

4 MATERIALS AND METHODS

4.1 DESIGN

In studies I and II a non-experimental and structured observational design was used to demonstrate the possibility to apply measurable performance indicators (I, II) and outcome indicators (II) in multidisciplinary full-scale exercises. Study III used a consensus method, the Delphi technique, to identify essential key indicators in disaster medical response. Study IV comprised mixed methods with a combination of qualitative and quantitative methods, a quasi-experimental design and a focus group discussion. Study V had a quantitative approach with a quasi-experimental and structured observational design. An overview of the studies is presented in Figure 7.

4.2 OVERVIEW

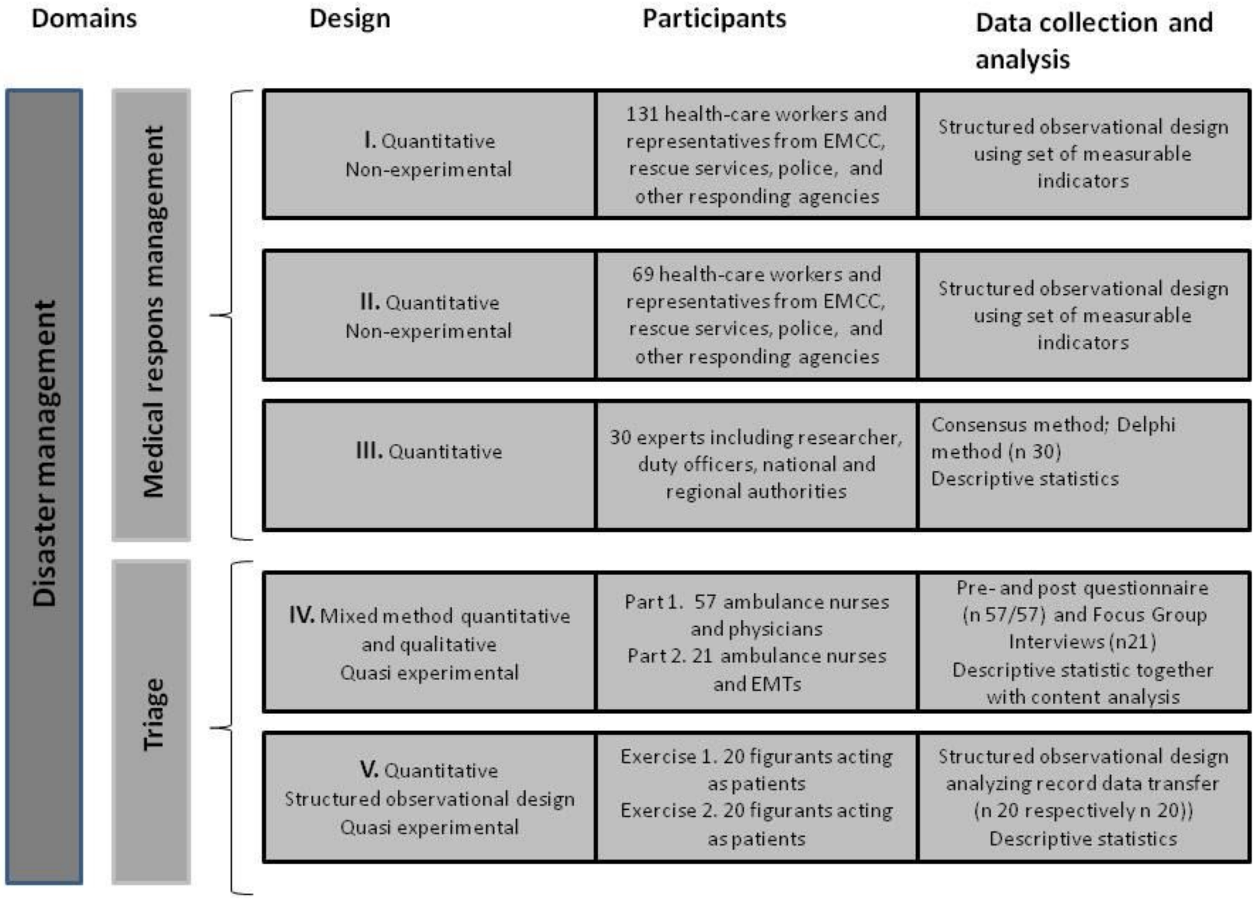

Figure 7 Overview of research questions and methods

4.3 STUDY AREA AND SETTINGS

Studies I, II and V were conducted at major airports located in different county councils in Sweden and in part are based on data from the same exercises. Study III was based on a Swedish national expert panel and Study IV was conducted in a pre-hospital setting in the SCC. Study V tested a technical support system during exercises and was performed in two parts; the first part was conducted in Finland involving a passenger ship accident, and the second part at a major airport in Sweden.

4.3.1 Health and medical care in Sweden

In an international perspective, Sweden is highly urbanised, with 85 percent of the population living in urban areas [167]. Sweden is divided into 20 autonomous health care county councils [168]. The Swedish population is covered by a public healthcare insurance system. This means that the health and medical services in Sweden are paid for by municipal and county council taxes [168]. Most of the tasks of municiple and county council healthcare authorities are regulated in special legislation (The Health and Medical Services Act and Social Services Act). General advice and regulations are based on these laws and administrated by the Swedish government agency, the National Board of Health and Welfare (NBHW) [169].

4.3.2 Emergency medical services in Stockholm county council

Stockholm is the capital of Sweden and a metropolitan region. Stockholm County Council is one of Europe’s largest healthcare providers with approximately 2 000 000 inhabitants [170]. Within this region, there are seven emergency hospitals and one of these is the region’s Level 1 trauma hospital. The core of the county council’s EMS is provided by road ambulances, emergency vehicles and helicopters organised under the local healthcare service, and is publicly/government funded [77]. Various pre-hospital providers run the ambulance service, all operating 24 hours a day. During the study period there were four different ambulance service providers, one of which was owned by the county council, the rest were private. The vehicles are stationed at ambulance stations or fire stations and alerted from the EMCC.

4.3.3 Civil Aviation

Commercial airports have substantial rescue resources regulated by the International Civil Aviation Organisation. The Swedish Transport Agency formulates regulations for civil aviation as well as control of safety and security. The airport operator is responsible for rescue planning, and for the initial emergency response, until emergency services such as the municipal fire department, police, medical services and other necessary agencies, arrives on the scene. The rescue plan should be designed in cooperation with and coordinated with the other emergency authorities involved [60]. According to national regulations, each airport has a mandate to perform a major incident exercise every other year [171].

4.4 DATA COLLECTION AND ANALYSIS OF STUDIES I-V

4.4.1 Participants and procedure

4.4.1.1 Study I

The accident simulated was an aircraft crashing while landing at a commercial airport. Participants were recruited from the airport rescue resources and responding agencies in the SCC area. The participants were representatives from EMCC (SOS Alarm), rescue services, police departments, EMS, hospitals and other responding agencies. The FSE was conducted in real-time. All the participants were professionals and alerted and dispatched according to the disaster preparedness plan. Communication between local and regional facilities was facilitated with a simulated EMCC regarding request for resources and hospital destination. One emergency hospital participated in the exercise as the designated health care facility, activating their management group and received injured patients from the major incident.

Figurants acted as injured/shocked/uninjured patients (n=99). All injuries were appropriate to what was to be expected in this type of incident. Each patient, had their injuries shown on a figurant-card, and each injury had predetermined medical requirements according to a specific template in the Emergo Train system (ETS) patient bank [149]. The patients' conditions were expressed in physiological parameters and their vital signs were assessed by EMS and hospital staff. During the exercise, specific treatment and transfer of patients were performed according to a "real-time" approach.

Templates with sets of measurable performance indicators (PI) for evaluation of command and control was used in Study I. The performance indicators covered early decision- making (management skills) and staff performance. These were based on specific standards (times and content) representing desirable performance of disaster medical management. Each template included 11 indicators graded as 0, 1 or 2 thereby giving a maximum achievable result of 22 points. Approval level was 11 points. Score 0 indicated that the standard was not met, score 1 that the standard was partly met, and score 2 indicated that performance had achieved the desirable standard within the stipulated time framework. These templates are presented in the appendices. Permission to use this model as well as the templates for evaluation was obtained from the developer of the concept [33, 40, 172].

Management performance was systematically and objectively scored and recorded by evaluators at two levels; regional level (in international literature often called strategic or gold level) and local level i.e. on-scene and in-hospital. The evaluators were certified instructors in a national concept for medical management at MIs [56]. The data collection was performed in cooperation with the Centre for Teaching and Research in Disaster Medicine and Traumatology (KMC), Linköping.

4.4.1.2 Study II

Participants were recruited from the airport rescue services and responding agencies in the county council of Östersund, Sweden. Study II had the same scenario design and participant criteria as in Study I except that figurants at the scene became virtual patients at the participating hospital (Table 1). Study II was also conducted with the same methodology as described in Study I, although this study included data from two full-scale exercises. The study-specific data were obtained using a simulation exercise tool with built-in evaluation possibilities, ETS, together with templates with sets of measurable quality indicators. In the ETS, each patient had predetermined medical requirements , thus enabling measurement of outcome indicators in terms of risk for preventable death or preventable complication [149], which was, in Study II, included as outcome indicators. The purpose of standardisation was to achieve a consistent approach producing comparable results. Observers on the scene and at the hospital were instructed to note triage category, medical treatment, and logistical issues such as transport time, for each patient. The data collection was performed in cooperation with the KMC, Linköping.

Table 1 Standardised full-scale exercises with built-in evaluation methodology used in Study II.

Scenario: Major Aircraft Accident		
	FSE I	**FSE II**
Commercial airport in Stockholm county council	X	
Commercial airport in Östersund county council		X
Multidisciplinary with representatives from; EMCC, rescue services, police, EMS , local and regional management groups, hospitals and other responding agencies including the airport rescue services	X	X
Simulation tool, ETS	X	X
Figurants acted as injured/shocked/uninjured patients on scene and at the hospital	X	
Figurants acted as injured/shocked/uninjured patients on scene but became virtual at the hospital by using ETS magnet symbols on whiteboards		X
Certified evaluators at designated areas	X	X
Observers at the scene and hospital	X	X
Templates with set of performance and staff procedure skills	X	X

4.4.1.3 Study III

Thirty experts were recruited by strategic selection and all accepted to participate. All experts were personally contacted (directly or by telephone). The experts were recruited from both research and practical fields, and included researchers, duty officers and representatives from national and regional authorities from various parts of Sweden. Most experts had more than 10 years of professional experience in the field of disaster medicine. All experts were informed about the consensus method, the Delphi technique, and the estimated time of commitment. Data collection was carried out using questionnaires answered between April and November 2012. A brief description of the Delphi technique: it is based on seeking experts' own opinions and comments on complex issues, and this process, using questionnaires (rounds), is repeated several times until consensus is reached. This study comprised three rounds. The first questionnaire was based on a review of the literature in the field, and the expertise and clinical experience of the researchers. After a pilot study on teachers who had knowledge and experience in disaster management, minor modifications were made to the statements in the questionnaire. The questionnaire contained a broad spectrum of statements grouped into eight predefined areas;(1) initial medical response management at the regional (strategic) level; (2) type of incident (incident characteristics); (3) initial medical response management at the local level (at the scene of the incident); (4) management/ liaison (in general); (5) patient transport/resources; (6) initial medical response management at the local level (healthcare facilities); (7) injury severity and mortality (patients characteristics); (8) staff equipment. In the first round, 85 statements on essential indicators concerning initial DMR were listed. Experts were asked to indicate their degree of agreement with each statement on a five-point Likert scale. The first questionnaire also included a glossary related to DMR. In the first round, the experts were encouraged to add additional comments and/or statements that they considered to be missing.

The consensus level, due to the relatively small group (n=30), was set at 80%. Consensus was thereby considered reached when 80% of the experts agreed on how important or non-important each statement was. After analysing Round 1, minor modifications were made to some statements based on participant comments so as to improve clarity. Furthermore, 25 statements that were considered not consistent with the aim of the study or were perceived as a replication were withdrawn. The experts suggested 71 new statements, and of these 37 were considered consistent with the aim and added to the final list. After this first process a final list of 97 statements was incorporated into the questionnaire for Round 2 and thereafter to Round 3. Statements where experts had reached consensus were shown, but could no longer be graded.

4.4.1.4 Study IV

Participants in the study were recruited from ambulance personnel of the SCC ambulance service. Individuals were asked to participate via their employers. All participants had education in the field of pre-hospital care and had gained the mandatory training and sessions on how to use the triage tool SMART Tag™. They worked in both central and peripheral areas of Stockholm. Most of the participants were male. Among those who responded to the survey and attended the FGIs, there were both new recruits and participants with many years of experience in pre-hospital care. Written information about the study was sent via email, as well as being on each ambulance provider's homepage.

A mixed method design, combining qualitative and quantitative methods, was used. The first part of the study was conducted as a survey of attitudes. Two identical surveys were conducted, before and after implementing a new strategy for triage tagging . The strategy consisted of a time-limited triage routine (nine months) that concerned the assignment of triage category and application of triage tags in the ambulance services day-to-day field triage. All ambulance personnel were instructed by their own ambulance providers to use the triage tool SMART Tag™ on all adult trauma patients referred to the Level 1 trauma centre.

First part: survey of attitudes

Data collection was carried out with two web surveys (pre- and post survey) that were available on a website and accessible four weeks before the intervention and four weeks after. Inclusion criteria for the surveys performed were EMS physicians and ambulance nurses. In the pre-survey163 of 376 (43%) participants answered the questionnaire and in the post-survey 88 of 362 (42%). Only participants who actively responded both times (57/57) were included in the study. The attitude questionnaire was developed by the author assisted by three co-authors and an external expert from Statistics Sweden. For validation the instrument was pilot tested on ten ambulance nurses all with knowledge and experience of field triage and SMART Tag™. Minor modifications were made to the questionnaire based on their feedback. According to instructions from the author each EMS provider put out information about the aims and method of the study on their homepage. The participants were asked to respond to statements regarding the use of triage tags by scoring on a Likert scale. In addition, a few open-ended questions provided the possibility for respondents to add information that could have been missed. The survey distribution was done online by IBM® SPSS Dimension Net Survey.

Second part: focus group study

Focus group members were recruited from ambulance nurses and EMTs employed in the ambulance service in SCC (n=21). The participants were selected on a purposeful sampling strategy as outlined by Patton [173] and were provided with written information by email. The interview guide was based on the results from the pre- and post surveys. The questions addressed the participants' attitudes regarding tagging and documentation and their experience with triage tags in MIs. Minor modifications of the questions were made after a pilot interview of one nurse with a good knowledge and experience of field triage in the pre-hospital setting. Before the FGI took place, the participants were informed verbally and written consent was obtained before interviews started. The focus group sessions were carried out over a three-week period in 2012. Three focus group sessions were held. In the first and second sessions, eight participants attended, in the third session five. Each session lasted about one hour. All sessions were recorded. Two research authors took part; one as a moderator and one as an observer. All group sessions were performed by the same moderator and were held at the work places of the participants. The opening question was *Please tell us about your thoughts on triage tags?* The group session continued with help of an interview guide. The guide was based on the results from the pre- and post surveys and served as a checklist to make sure that all topics were covered. Seven main areas were explored tin the group sessions; (1) education, (2) utilisation (3) decision-making (4) routine (5) knowledge and skill (6) experience (7) documentation. The participants were encouraged to speak freely, and the moderator asked follow-up questions when necessary.

4.4.1.5 Study V

In two separate simulated major incidents, 20 figurants in each setting were selected for inclusion (Table 2). A technical support system, Radio Frequency Identification (RFID) was tested as to its feasibility in providing information on patient tracking (number) and triage category selected. Figurants who acted as patients were tagged with both an RFID-tag and the national paper triage tag. An RFID-tag was attached to each card. Medical personnel and figurants received verbal instructions how to handle the triage-tags and triage-phone before the exercise started. Each patient had their injuries shown on a figurant-card, describing his/her simulated injury profile. The triage category was pre-selected and pre-defined for the RFID-system. Based on the injury profile the simulated patients were triaged by medical personal participating in the exercise or by the figurants. Of the Finnish patients, in exercise 1: five were classified as category 1, five as category 2 and ten as category 3. Data on two patients could not be recorded, and were excluded. Of the Swedish patients in exercise 2 only 17 of the 20 selected were sent to the emergency hospital participating in the exercise. Of these, eight were classified as category 1, three as category 2 and six as category 3. Data on eight patients could not be recorded, and were excluded.

Technical support system

The technology in this test setting was used to support timely access to critical information, and was compared with traditional paper triage tags. All technology was run by technical coordinators positioned at designated areas. Triage documentation was done using both the RFID-based system, which automatically sent data to the medical commander, and a traditional method using paper triage tags, logged manually. The situational awareness of the medical commander was measured by comparing the availability of up-to date information at different points in the medical care chain using both systems.

The data logged in the RFID-system provided time-tagged information. Technology used utilises commercially available components, including RFID and mobile phone technology. Technologies such as Global System for Mobile Communications (GSM) and the Global Positioning System (GPS) are the basis for mobile user-interfaces [174]. The system consists of the following components, also shown in Figure 8;

- A mobile phone- triage phone (equipped with an integrated RFID read/writer)
- RFID-tags (electronic tags)
- mTriage® software application (Logica CMG Co., Finland) allows the triage category assigned to each patient to be registered. Once a patient is assigned a triage category, the programme automatically sends a message to the Nokia SM and stores it on the patient’s personal RFID tag.
- Triage-PC (Laptop/or PCs with Logica “Merlot Medi Mobile” software placed at different levels of medical management)
- Triage-service (receives, store and distributes triage information to all levels of medical management, system Logica “Merlot Medi Server”)
- Triage-web (website and means to access information on patients and their evacuation) was used to access information by the medical management at the regional level and at the receiving hospital.

Triage with *RFID-tags* consists of the following steps: (1) hold the RFID- tag in front of the mobile phone device, (2) check the triage category on the display of the mobile device, (3) change category if necessary (4) hold the patient tag in front of the mobile phone device a second time. The usability of the RFID system in the Swedish exercise incident was assessed by a questionnaire. The questionnaire contained eight sections with a total of 27 questions regarding the patients’ subjective confidence in the personal use, general use, and applicability of the system. A section for comments was included at the end of the questionnaire.

Table 2 Tagged figurants acting as patients in exercise 1 (Finland) and 2 (Sweden).
*Only 17 of selected 20 were sent to the participating emergency hospital.

At the scene of the incident	Exercise 1	Exercise 2
Figurants (n) tagged with both an RFID-tag and paper triage tag	20	20 (17*)
Triage category		
1 (Red)	5	8
2 (Yellow)	5	3
3 (Green)	10	6

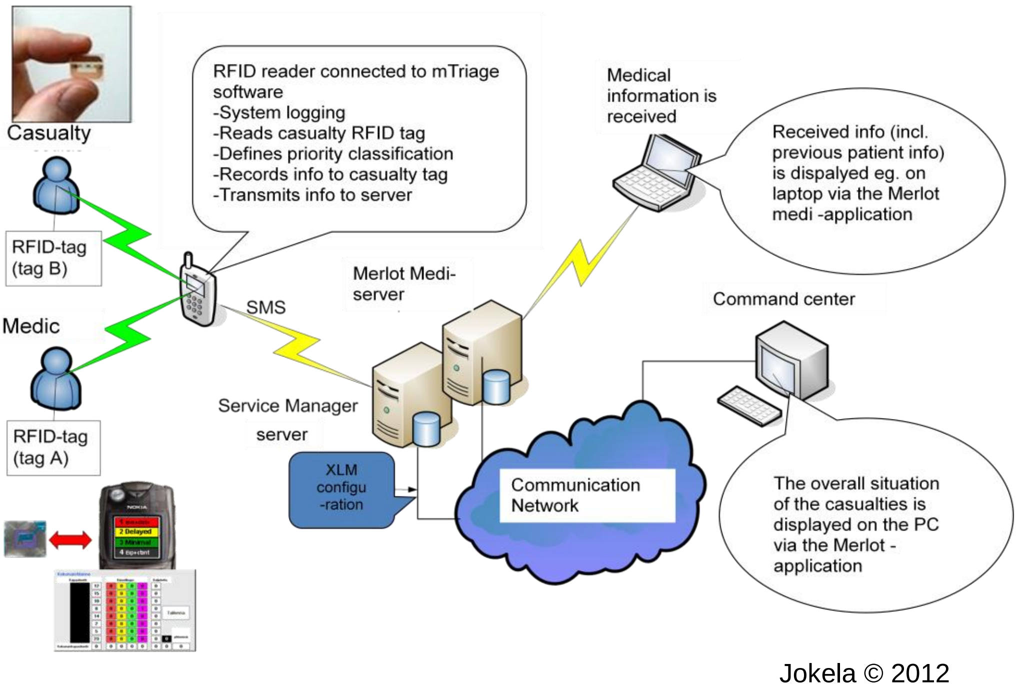

Figure 8 RFID system operation layout

4.4.2 Data analysis

Standardised templates each with a set of measurable performance indicators, and the simulation system ETS were used to obtain objective assessment of disaster medical management and subsequent patient outcome (I-II). By using indicators for evaluation, it is possible to demonstrate data numerically. The process of analysing data from a modified Delphi technique involved quantitative data. Questionnaires were sent out in three rounds to an expert group in order to reach consensus on the essential key indicators that should be included in a nationwide protocol for the documentation of disaster medical response (III). Statistical analysis was used for the pre-and post questionnaires obtained in the first part of Study IV, and a qualitative content analysis was used for the data obtained from the transcribed focus group interviews in the second part (IV). The differences in outcome between applicability of triage RFID system and paper-based triage tags were measured in Study V.

4.4.2.1 Study 1

Templates with set of performance indicators address a required level of achievement assessed as being correct, partly or incorrect. These templates were used as protocols for the evaluation of performance at two different levels of medical management, regional level (in international literature often called strategic or gold level) and local level i.e. on-scene and hospital. All data were registered by evaluators with interpretation of the phenomenon under study. This helps to ensure that each evaluator scores different processes in the same way. Data from each management level was analyzed and expressed numerically. Eleven out of 22 points were considered satisfactory. These templates are presented as appendices.

4.4.2.2 Study II

Total scores of performance indicators and staff procedure skills were calculated at different medical management levels using the same templates as in Study I. All data were registered by evaluators with interpretation of the phenomenon under consideration made under the same conditions as in Study I. Furthermore, all logistical and clinical data regarding patient care were registered at the scene of the incident and at the hospital. The patient outcome indicator was evaluated in terms of risk for preventable death or complication. Each patient was assigned to specific measures required in order to be expected to have a favourable outcome, all according to the templates included in the ETS. If these measures were not taken or performed too late, according to the ETS stipulated time framework, the patient was judged to be at risk for preventable complication or death. In each setting 2008 (I) and 2010 (II) one emergency hospital participated, and received 17 victims. The results of performance and outcome indicators were calculated and enabled comparison between the two settings (I-II).

4.4.2.3 Study III

Data from the questionnaires were analysed statistically. The first returned questionnaires were analysed by using frequency output from SPSS. Statements that had not reached the predetermined consensus level of 80% were sent out again as part of the Delphi process [175]. In this process all subsequent rounds incorporated the results of feedback from the previous round. Thereby statements had the chance to gain consensus status if some experts modified their response. For data analysis, the experts were treated as a homogenous group and the five-point Likert scale was tricotomized to a three- point Likert scale where scores 1–2 represented "totally disagree", 3 represented "neutral" and scores 4-5 represented "totally agree", as used in other studies [176, 177] . Data were analysed using SPSS statistics version 21 to measure percentage (%), central tendency (mean) and dispersion level (standard deviation).

4.4.2.4 Study IV

First part: survey of attitudes and intervention

This survey involved statistical and analytic procedures. The questionnaires were used to measure change in attitudes and experiences. This kind of data collection can be used to measure the efficacy of a strategy or programme. As the study involved two sets of data on the same group of participants it could be seen as a variation of a cross-sectional design to determine if a change had occurred. Data were extracted from the survey base (IBM® SPSS Dimension net survey) and entered into SPSS® statistics version 21 to analyse the findings. The data were analysed using the Wilcoxon matched pairs statistical test to compare the pre- and post survey data (data of two groups including the same participants). P -value of less than 0.05 was considered significant.

Second part: content analysis of focus group sessions

The transcribed text from the focus group interviews was analysed using a qualitative content analysis described by Graneheim and Lundman [178]. Firstly the text was independently read by two authors several times in order to capture an overall impression of the text. Thereafter meaning units were extracted and condensed. The condensed meaning units were labelled with a code. By continuously comparing the codes for similarities and differences subcategories emerged. The subcategories were discussed several times before reaching agreement on categorisation. Finally four categories were grouped into one overall category.

4.4.2.5 Study V

Data were analysed as regards tagging patients with RFID-tags and the information distributed as well as tagging patients with paper triage-tags in the control group. The technological suitability of the system for field use was measure by analysing the recorded data transfers, tag events and the amount of failed data. Data collected from the exercise were entered in spreadsheets using Microsoft Excel and statistical analysis was performed by SPSS® statistics version 17. In Sweden a questionnaire was used in the exercise setting to measure the subjective impression of the use and applicability of the RFID system. Percentages were used for describing their impression of the system.

4.5 **ETHICAL CONSIDERATIONS**

All studies in this thesis were performed in accordance with the World Medical Association, Declaration of Helsinki[179]. The participants in all five studies received verbal and written information about the nature and purpose of the studies.The participants in Studies I, II and V were informed about the purpose of the evaluation method of managements groups and the RFID technique. Furthermore, the participants were assured of the confidentiality of the information they provided and that their anonymity would be ensured in any reports emanating from the study. The experts in the consensus group were informed by both telephone and email about the purpose of the study and asked if they were willing to participate (III). Their participation was fully voluntary, and a cover letter to the experts informed them that they were free to withdraw without providing a specific reason.

Application for ethical approval in Study IV was sent to the Regional Ethics Review Board, Karolinska Institute (reg.no. 2011/502-31). The regional board’s decision was that approval by an ethics committee was not necessary because the study does not involve any sensitive patient data referred to in § 3 Ethical Review Act. All participants in the web survey questionnaire were informed that their participation was voluntary. A cover letter to the participants in the focus groups informed them that participation was voluntary and that they were free to withdraw without providing a specific reason. Participants in the focus groups were informed that the interview was recorded. Before starting the focus group interviews in Study IV, the participants were informed about the method of data collection and confidentiality, and they provided informed written consent.

5 RESULTS

The results section consists of a description of the results of each study (I-IV), followed by a summary.

5.1 STUDY I

This study shows that performance indicators can be used for the evaluation of command and control in multidisciplinary full-scale exercises. Using this tool, performance could be graded and compared with reference value according to the template. By using standard scores for evaluation, it is possible to demonstrate results numerically. This study used cumulative scores as a means to evaluate the effectiveness of medical management i.e. how well expected processes were performed to achieve the optimal result. The findings of this study indicate problem areas that need attention if we are to meet desired management system performance standards.

The poorest result was seen in pre-hospital management, scoring three points out of a possible 22 (Table 3). This result indicates a discrepancy between information required by regional management and the information actually sent from the medical commander at the scene. This also was reflected in the problems experienced at the scene of the incident, due to delays in information and evacuation of the injured. Furthermore, several measures were left out for example; first report to dispatch, content on first report, formulate guidelines for response, liaison with fire and police and second report from scene. The total scores for initial strategic management and staff procedure skills were 15 out of 22 and 21 out of 22 for the two exercises (Table 3). Evaluation of performance of the strategic management indicated that decisions made to send additional resources to the scene, providing guidelines for the referring hospitals, and the selection of receiving hospitals were accomplished correctly and within the stipulated time framework. All other performance indicators were only accomplished in part. The difficulty in making proper and timely decisions was the result of inadequate information from the scene of the incident.

Furthermore, evaluation of the performance of the hospital management group indicated failure to take an initial decision regarding level of preparedness. All other performance indicators were performed correctly and within the standard time framework established. The major difference between performance in staff skills at strategic and hospital management levels was related to telephone discipline. The total scores for the hospital management group were 17 for command and control, and 21 for staff procedure skills (Table 3).

Table 3 Results expressed in points from two, full-scale exercises based on templates of performance indicators. *Maximum score was 22 points in each category where 11 different indicators were given 0, 1 or 2 points.

Performance indicators	**FSE I**		**FSE II**	
	Category		**Category**	
	Command & control*	Staff procedure skills*	Command & control*	Staff Procedure skills*
Pre-hospital (local level)	3	Not assessed	15	Not assessed
Regional	15	17	18	21
Hospital (local level)	17	21	17	20

5.2 STUDY II

This study shows the possibility of conducting standardised full-scale exercises with a built-in evaluation methodology that can produce comparable results. Templates with a set of performance indicators, identical to Study I, were used in combination with outcome indicators to assess disaster medical management at different levels. The pre-hospital command and control scored 15 points out of 22 points, which implies that the structure of field management was slightly better than the acceptable level, but could still be improved. The total scores for command and control for the strategic and hospital management levels were 18 and17 points respectively and staff procedure skills 21 and 20 points respectively (Table 3).

The evaluation model exposed several problems faced in the initial decision-making process that were repeatedly observed and had major impact on patient outcome. For example, insufficient reporting and inconsistent coordination between responders that limited the ability to evacuate severely injured patients, and resulted in comparatively high numbers of risk for preventable death and complications. In FSE I and II five respectively seven of 17 severely injured patients were at risk for preventable death (Table 4). Despite sufficient access to ambulances in both exercises, failure of rapid evacuation indicates that decisions made in this context were less than optimal, and possibly a major reason for poor patient outcome (I, II) . All data regarding performance during the exercises as well as all data regarding patient outcome were obtained and expressed in terms of risk for preventable death and/or preventable complications. Both FSE I and II could thus be compared regarding performance (process) as well as outcome (result) indicators (Tables 3 and 4).

Table 4 Patient outcome expressed as risk for preventable complications and preventable death in two full-scale exercises. *All 17 patients received at the participating hospital were at risk, according to the ETS template for risk for unfavourable outcome expressed as preventable complication or preventable death

Outcome indicators	FSE I	FSE II
Risk for preventable complication	53% (9/17*)	29% (5/17*)
Risk for preventable death	29% (5/17*)	41% (7/17*)

5.3 STUDY III

This study shows that the Delphi technique can be used to achieve consensus on what is considered to be essential information in order to gather relevant data on a disaster medical response. After three rounds, 77 statements of 97 reached the predetermined consensus level (80 %) and 20 did not. The distribution of the experts is shown in Table 5.

Round 1 included 97 statements, in which 44 statements reached consensus, leaving 53 that were returned to the expert group in Round 2. After Round 2, 12 statements of 53 reached consensus, leaving 41 statements that was returned to the final Round. A further 21 statements reached consensus after Round 3.

In Round 1, the expert group generally agreed that data concerning notification, incident characteristics, first reports, coordination, alerting hospitals, mobilisation of transport, communication and information, have an essential role in the activation of a disaster medical response, and should be included in a standard protocol. *In Round 2,* 21% (8/37) of the statements suggested by the experts reached consensus. The statements mainly included additional time points, processes involved in triage, and content of reports as well as decisions. In the areas injury severity and mortality, as well as patient characteristics, all statements reached expert consensus after Round 2. Content of reports and decisions in the area" initial medical response management at the local level" and "first unit on scene" reached expert consensus. *In Round 3*, 12 of 13 statements regarding the areas management/liaison, incident management in liaison with other agencies, and 26 of 31 statements regarding scene management, reached expert consensus. Of the 37 statements suggested by the experts there were 29 included in Round 3, and out of these 52% (15/29) reached consensus. In all, after three Rounds, 79% (77/97) of the statements reached expert consensus with a mean rating varying between 4.20 and 4.96 (SD 0.18-1.10). The 77 statements that did reach consensus covered most aspects involved in the initial disaster medical response. Among the statements that did not reach expert consensus, initial medical management at healthcare facilities received the lowest value 3.07 (SD 1.15). The 20 indicators that did not reach consensus mostly concerned patient-related times in hospital, type of support system, and security of healthcare personnel. The mean for the 20 statements that did not reach expert consensus ranged from 3.07 to 4.32 (SD 0.76-1.32).

Table 5 Number of experts participating in each of three Rounds of the Delphi study, and their affiliations.

Affiliation of the expert group	Round 1	Round 2	Round 3
Researchers	10 (33.3 %)	10 (33.3 %)	10 (33.3 %)
Duty officers (Regional level)	10 (33.3 %)	10 (33.3 %)	10 (33.3 %)
Other national/regional authorities	10 (33.3 %)	9 (30 %)	9 (30 %)
Total participant	**30 (100 %)**	**29 (96.6 %)**	**29 (96.6 %)**

5.4 STUDY IV

The findings in the first, quantitative part of the study showed that the use of triage tags in real incidents is relatively low and infrequent use of triage tags makes it hard to become familiar with and see the benefit of using tags. The FGIs revealed that experienced ambulance staff rely more on their own experience, knowledge and know-how when assessing the patient. The findings in the second, qualitative part of the study are represented by the overall category: *Need for daily routine when failure in practise.*

First part: survey of attitudes

Only participants who actively responded both times (57/57) were included in the study. The findings revealed three significant differences before and after the intervention with daily use of triage tags on adult trauma patients. First; more are prone to use SMART Tag™ after the intervention when there are several patients to triage. Second; after the intervention the participants consider the sort scoring system to be more valuable. Third; they consider the time consumption when using the system to be more after the intervention. The participants do believe in the usefulness of field triage but low application of triage tags emphasize that the tags are not used frequently. The participants expressed that few exercises and infrequently use of triage tags in daily practice makes it hard for them to become familiar and to see the benefit of using tags. Despite a standardized system of simple triage algorithms and a card that combines priority selection (triage tag) and documentation the infrequently used triage tool don't

enable participants to feel comfortable with the system in practice.
Second part: focus group study

The findings in the second part of the study are represented by the overall category: *Need for daily routine when failure in practice*. In the analysis four categories and 13 subcategories emerged Table 6. The four categories formed the overall category as stated above.

Table 6 Categories and subcategories

Categories	Subcategories
Perceived usability	Perceived loss of time
	Interfering with medical procedures
	Triage tag design (folding design)
	Deviating from standard operating procedure
Daily routine	Familiarity with the equipment
	Need for confidence
	Need for regular training
	Lack of motivation
	Need for routine practice
Documentation	Time-consuming
	Recording of information
Need for organisational strategies	Need for guidelines
	Follow-up

Perceived usability

In this category the participants describe how they use theory and experience in their assessment of critical injured patients and severity of injuries. Experienced ambulance staff is less likely to use the triage tool. They feel that the triage tag is too detailed and that recording information on triage tags interfere with medical care of injured. In the subcategory, *perceived loss of time* the participants stated that they don't have time to use the tags and that experienced ambulance personnel will not necessarily see the system as a help, and furthermore are less willing to use them at all. They rely more on experience, knowledge and their own know-how when assessing the patient. In subcategory, *interfering with medical procedure.* the participants described that due to the necessity of medical care being provided under stress and lack of time recording of information on triage tags are perceived as taking time from assessment and care of the patient. In subcategory, *triage tag design* the participants perceived triage algorithms, the tag colour code and the ability to change and communicate the priority assigned as positively. In subcategory, *deviating from standard operating procedure* the participants highlighted the problems of applying a system that are rarely used in daily practice. In a stressful situation one relies on what is proven and familiar.

Daily routine

This category includes the issue of familiarity. Some of the concerns expressed by the participants' were the relatively low incidence of severe trauma cases and infrequency of major incidents. In subcategory, *familiarity with the equipment* the participants understood the benefits of the triage system but expressed multiple reasons why the tags are not used in daily routine. Not being sufficiently familiar with the triage tool was considered a weakness and a reason to the low use. One of reason is that MIs are rare, but they also admitted that it might be their own choice not to use the tag when they could have done so. In subcategory *need for confidence* the effect of not using the triage tags was discussed by the participants, they made it clear that it is one thing to be educated and trained in a triage system, but it also needs to be applied in real situations. In subcategory, *need for regular training* due to the lack of regular training, in using the triage tags and low frequency of major incidents, the participants expressed discomfort with the tool despite their theoretical knowledge of the system. In the subcategory, *lack of motivation* the participants also addressed that ED personnel rarely listen to their reports, or read the records. Which give the lack of motivation to use the triage tags. In subcategory, *need for routine practice,* the participants expressed the fact that they only have a limited amount of training, which makes them feel less secure using the triage system. The participants suggest a means of training that incorporates the triage tags in their daily routine.

Documentation

The participants perceived documentation of information and observations on the tag as time-consuming, affecting the assessment and treatment of the patient. Yet they were aware that documentation is essential for systematic reassessment. The subcategory, *time-consuming* indicates that very few of the ambulance staff in this study kept patient records. Lack of time was a common explanation or they gave no priority to that kind of task. In subcategory, *to record information* the participants highlight the importance of quality assurance of reports. Contributing factors to the lack of recording included too much information to fill in, time consuming but also forgetfulness.

Need for organisational strategies

The participants emphasized that limited use in daily practice and absence of clear guidelines was important factors. Based on participants' comments, the absence of clear guidelines seams to contribute to uncertainty in the use of the tags because the system is not used regularly enough. In subcategory, *need for guidelines* the participants, described specific demands to maintain the knowledge and skills within the triage system and they expressed their opinions regarding the need for clear guidelines on when the triage tags should be used. In subcategory, *follow-up* the participants, stated that all ambulance entrepreneurs must have the same approach in the application of the triage system and that is a task for the medical incident commander on scene to order it. At the local level, they believe that there ought to be persons responible who can follow -up the regularly use of the tool.

5.5 STUDY V

This study showed that when using RFID tags, patient information was forwarded on average 47 minutes faster in Exercise 1 and on average 68 minutes faster in Exercise 2 compared to the traditional reporting. The technological suitability of the RFID system for field use was measured by analysing data transmission, comparing the time it took to communicate patient priority to the receiving hospital and the hospital management group with the paper based system. As the triage information was available on line, it was possible to make decisions based on a much improved situational awareness.

The RFID system provided a timely and accurate picture of the prevailing situation. According to these quantitative results, the RFID system seems to be the most effective alternative. In Exercise 1 the feasibility of the new triage system was evaluated using a standard post-exercise questionnaire. System users found the RFID mobile system easy to use, and did not consider it more arduous than using the traditional paper tags. The users further found the system to be a help in their work, and to be no more time-consuming than when using traditional methods.

5.6 SUMMARY OF RESULTS

The results from these studies increase our knowledge about the applicability of standardised training models with built-in evaluation possibilities to simulation exercises of major incidents. The results show that standardised exercises can produce comparable results and that decisions not taken according to standard protocols may influence patient outcome. By using performance indicators, it is possible to find the crucial decisions that are related to patient outcome. Furthermore, the key indicators, process, structure and outcome, were identified in an expert consensus process (Delphi) to guide us as to what is essential in a standardised nationwide protocol for the documentation of a major incident response. Moreover, the attitudes and experiences of ambulance personnel towards practicing triage tagging in the pre-hospital setting showed that there is a need for standard practice to maintain familiarity. The ambulance personnel do not see paper-based triage tags as a necessary tool in their day-to-day work and are thus less likely to use them. A technical support system for triage information in EMS was shown to create a better awareness of the medical care situation than traditional triage tags, thereby improving medical management in major incidents.

6 DISCUSSION

6.1 GENERAL DISCUSSION

In disaster preparedness, education and training is essential to prepare professionals for their specific role in the medical response. It is of importance to focus on evidence-based best practice as well as knowledge and understanding gained by experience i.e. lessons learned. As stated previously a common way to share experiences of best practices across the international emergency services system (EMS) community, is through lessons learned as concluded in descriptive studies. Until recently objective evaluation of medical responses has not received proper attention.

6.1.1 Preparedness

Even though it seems evident that effective management relies on clear coordination of available resources and effective communication, these areas are commonly identified as weaknesses in medical response [29, 69, 87, 88]. This is linked to issues related to the use of indicators in disaster medical response and management. In this thesis the application of measurable performance indicators in full-scale exercises, mimicking standard management procedures, showed weaknesses in management decisions that touched upon these areas. Even if there are structural and organisational variations in emergency preparedness systems between international EMS communities, the basic management principles are the same [3, 17, 57, 68]. These similarities enable the development of quality control tools and identification of accurate key indicators in the field of disaster medical response [33, 50, 146].

Following the Swedish national management doctrine, we have used a quality control tool in Studies I and II. This tool has been used for many years to evaluate performance in Swedish disaster management education and training [31, 33, 41, 57, 72, 146]. In a review of the literature on preparedness training, Potter et al. [145] showed the absence of standard evaluation of education and training. They emphasise that training outcome should be measured by performance improvement in field exercises. Access to up-to-date education and simulation models with built-in evaluation methodology may help teachers and organisations to facilitate meaningful learning in order to reach the standards desired in disaster medical response. Such measures should improve the value of exercises. During the last decade, objective evaluation using quality indicators has developed to become the standard measure of pre-hospital medical response in Sweden. A few county councils are currently making efforts at hospital and regional medical response levels, to implement indicators as a quality control tool. Further development of hospital and regional medical management is in progress.

6.1.2 Evaluation methodology

The evaluation method described in this thesis was based upon measurable performance indicators developed by Rüter [33, 40, 172] (I, II). Quality indicators reflect what is considered good or poor performance, based on standards established and accepted by the organisation [56]. When standards are not met, there is room for improvement. These processes and expected outcomes must be realistic and developed in a way that allows performance to be systematically studied and analysed, providing the possibility to compare results and experiences [27, 30]. From a quality improvement perspective it is important to study the link between process and outcomes indicators in relation to set standard [156, 157]. In these studies, some of the indicators may have been crucial for the outcome, and the impact of not meeting the standards desired. However, discussions in this thesis focus more on the methodology than the results of the exercises *per se*. Furthermore, by using the evaluation model proposed, adaptation of the organisation may need to be carried out, and each agency will have the increased possibility to specifically identify what aspects of command and control that needs to be improved or further evaluated. Such follow-up measures could include further education and training that utilise the standards against which the level of performance is measured.

Disaster exercises are frequently used to test and evaluate the capabilities and capacity of medical response systems in major incidents [21, 137]. However, until now there have been limited attempts to scientifically analyse outcome of the response [17]. Furthermore, generalised evaluation of training effectiveness is rare because of the diversity in study designs [26, 50, 144]. As a result, there is no universally accepted method for performance measurement. Through simulation exercises, Nilsson et al. [72] showed that it is possible to relate management of resources in major incidents to patient outcome. By using measurable performance indicators, it may be possible to define the essential decisions that are related to patient outcome. This is supported by an experimental simulation [155] showing that performance indicators, using the simulation tool ETS, are applicable and that reproducible results can be used as a basis for the improvement of response plans.

Studies I and II demonstrate that a standardised evaluation method with measurable performance indicators that are part of a validation process, can identify areas in initial medical response and management where there is room for improvement. The performance indicators in these studies detected failure in first reports from the scene to regional management (I). Communication and information were not clear and concise (I, II) and this may have had a negative impact on the evacuation process of patients resulting in a higher number of preventable deaths (II). Despite access to available ambulances in both exercises, failure of rapid evacuation indicates that decisions made in this context were less than optimal and could possibly have been reflected in patient outcome. This indicates that the sharing of information, follow-up, and coordinated decision-making between involved agencies was inadequate. The reason why the considerable difference in pre-hospital management decision performances between Exercise I (3 out of possible 22) and II (15 out of possible 22) was not reflected in patient outcome cannot, however, be explained. This is something that may have to be addressed using other research methods. Circumstances at the scene such as time-period, geography, weather conditions, reliable communication systems and security are other essential factors that may affect the response and therefore must be considered in the assessment. This problem was recently described following a real aircraft incident where there were difficulties in evacuating the victims, and this delayed transport of victims to receiving hospitals [18].

Studies I and II provided objective judgments on the quality of management in a reliable and valid manner. Even so, there is a need to study whether timely decisions or actions are more important than the quality of the performance. Furthermore, the combination of process and outcome complies with the desirable goal to understand the relationship between management procedures and patient outcome (morbidity and mortality) [12]. Moreover, the quality of being reproducible makes it possible to measure and monitor quality and efficiency over time, corresponding entirely with the objectives of the Swedish healthcare system [59]. Standardised evaluation models with reproducible results and comparison of results are necessary for scientific analysis if we are to define best performance practice for use in improvement and adaption of the organisation [17]. In recent years, awareness of the needs and benefits of disaster management skills has increased in the community [180]. Terrorist incidents in Madrid 2004 [115], London 2005 [181] and Oslo 2011 [122] represent the type of unpredictable incident that EMS providers have to be prepared for. Experiences from Oslo 2011, presented in a retrospective observational report, state that well-developed disaster plans, tested through incident exercises, are of crucial importance for the quality of medical care of those affected [180]. Every major incident is unique and provides lessons for those involved. Identification and use of relevant indicators is a crucial part of determining the impact of interventions in medical response [50]. At the same time several studies indicate that current evidence on the effectiveness of preparedness training is limited [9, 19]. Furthermore, it is important to see not only evaluation as an integral part of disaster exercises but also to choose the best methodology that can provide sustainable knowledge.

Gathering data in a standardised manner will most likely facilitate experimental research and increase our understanding regarding the effectiveness of optimal disaster medical response [30]. Franc et al. [41] used nine performance indicators developed by Rüter [172] that they considered relevant for their own management system. Time to achieve the standard was compared with the time framework for indicators used in this thesis. It is essential, however, to consider the applicability of the indicators in relation to different organisational aspects, and the possibility to define a performance standard. The strength of the quality indicators used is that these indicators have been demonstrated to be useful in day-to-day practice also (I, II). In this respect it is of outmost importance to examine the indicators usefulness and relevance to the organisation using it, as well as the setting in which they are used. Since major incidents occur infrequently, the fundamental principles of medical management favours a doctrine based on the daily procedures and routines of EMS and healthcare providers [70]. The application of major incident procedures in everyday practice has several benefits: they become familiar and easy to apply when indicated; procedures that work well in daily practice will probably also work well in a major incident; the problem of using procedures that departure from everyday practice in medical management, the so-called "doctrine of daily routine" as described by Garner, is avoided [70]. Furthermore, personnel can easily become stressed in unfamiliar situations and will therefore tend to follow their usual pattern of behavior. The indicators used in Studies I and II have become what is considered to be the standard for pre-hospital medical response in Sweden. This may solve the issues described above.

6.1.3 Reporting disaster data

To date, research in disaster medical response has mostly focused on educational and training models. The reason for this is the difficulty in obtaining data from "real" incidents. EMS documentation is often sparse or incomplete, hampering evaluation of DMR and loss of data for research [33, 159]. Study III identified key indicators essential for disaster medical response, providing guidance as to what should be included in a standardised nationwide protocol for the documentation of a major incident response. Our results indicate that there is a general consensus among experts on the importance of data transfer during the initial medical response. However, this was no surprise since most experts in disaster medicine consider that the greatest chance to influence the outcome of a major incident is during the initial phase [17] . The group of experts agreed that notification, incident characteristics, first reports, coordination, alerting hospitals, mobilisation of transport, communication and information, are essential data that must be registered. The statements selected strengthen the value of the indicators used in Studies I and II concerning pre-hospital and strategic management performance. Most notable, however, was that consensus concerning triage documentation was first met in the final round and the use of triage tags did not reach consensus. This is surprising since triage is one of the most important aspects of a DMR, but there are few reports providing information on how triage is actually employed [22]. In Study IV, participants observed that experienced ambulance personnel do not see triage tags as a necessary tool and are less likely to use them. One way to ensure the use of triage tags is to confirm that they really have been used in the disaster medical response, otherwise it remains up to each individual to use them. Several studies emphasise the importance of triage at the incident site, and that triage should not be deferred to the receiving healthcare facility, since this most certainly will overwhelm the hospital's capacity to treat severely injured patients [46, 121]. For this reason we tested a technical support system which is accessible to and easily used by the ambulance service, so as to achieve better awareness of the mass casualty situation, thereby improving decision-making during the initial medical response (V).

Major incidents are complex and difficult to manage. In these situations contextual factors such as time pressure and continually changing conditions, ought to be understood as regards the ability to handle difficult tasks [94]. Documentation of ongoing activities is a prerequisite for evaluation and follow-up of the effectiveness of the response and analysis of results [50]. According to the current regulations, preparedness should be based on five components in which evaluation and follow-up are essential (planning, equipment, education-training-exercises, medical management, evaluation and follow-up) [56]. However, EMS documentation is often inadequate, hampering evaluation of medical response and loss of data for research [33, 122, 159]. Efforts have been made to develop different technical support systems for information, timely storage of accurate data, and to facilitate situational awareness [55, 172]. Even though such systems have been developed, paper-based triage tags and logs are still in use. To achieve relevant data, we need to incorporate indicators which allow assessment and comparison leading to quality improvement (I, II, III).

There is a need to share sustainable knowledge within international EMS communities [166]. It is reasonable to believe that adequate data from the initial response will provide clues on how to improve medical responses in the future. If important standard processes in this phase are documented and time-logged, this may well result in the identification of weak links in the early phase of the response chain, and also where communication and reporting requires improvement. At the same time, we have to consider the need for qualitative data such as content of reports, since time-logs alone without procedure content may have limited value.

Healthcare authorities in several countries have given priority to the development of national registers to be used as a basis for audit, quality improvement and research. As yet there are few protocols developed for reporting disaster medical response in a standardized manner [197]. So far no studies on medical response management have reported results leading to a suggested protocol, which emphasises the gap between research and practice in disaster medicine. The level of scientific evidence behind many of our actions remains weak [39].

A majority of the indicators in Study III are to a great extent identical to those previous recommended by Debacker et al. [50]. This indicates that the processes and general principles for disaster medical response are based on the same fundamental activities despite differences in DMR structure and resources in different countries. The use of protocols for collecting and reporting medical response can be used to determine where further teaching and practice in response management is required, to enhance the planning and response to future incidents, and to see if processes contribute to the outcome. Furthermore, by using the same indicators in the evaluation of real incidents, and relating these to available patient data, it should be possible not only to compare the performance indicators but also to validate the outcome indicators chosen for the exercise.

Finally, it is difficult to reach agreement on an international standard template for collecting and reporting disaster medical response data, since each country has its own management structure and an international data reporting system may not be feasible. Nevertheless, we have to start identifying accurate key indicators for the evaluation of medical response performance. The consensus process and selected statements in the present study (III) will be presented at a national level, where the possibility of them being included in training as well as in practice programmes will be discussed and further developed.

6.1.4 Triage tags and technical support systems

Triage is an important process in disaster medical response. It is in this process that decisions made have an important impact on patient outcome (morbidity, mortality) [3, 95, 111]. The triage process is the link between organisational management and patient management. An essential part of initial assessment is to tag each patient in order to make patient triage easily recognisable thus making it possible to communicate triage categories and increase situational awareness. With the help of triage tags and written documentation, medical personnel are able to effectively and efficiently ensure that critically injured patients are transported to appropriate health- care facilities [88, 117]. This is how the triage process is meant to work. However, the current state of documentation of triage activities, despite a proliferation of triage tag and digital systems, remains poor [123]. In this thesis (IV) the most important answers in the quantitative part of the questionnaire revealed that ambulance personnel believe in the usefulness of field triage, but the low application of triage tags indicates that tags are not used frequently. It has previously been described that being familiar with the equipment in the ambulance is important for the sense of security which leads to full utilisation of the equipment [24]. Furthermore, findings indicate that few exercises and the infrequent use of triage tags in daily practice makes it harder to see the benefit of using tags (IV). This concurs with Abelsson et al [14] conclusion that continuous practice and use of equipment sharpens and maintains skills. Furthermore, the results of Rivasi et al. [22] indicate that deterioration in skill is associated with the infrequent use of triage systems.

In Study IV quantitative findings were confirmed by the qualitative results. Despite a standardised system with simple triage algorithms and a triage card that combines priority selection (triage tag) and documentation, the infrequent use of triage tools leaves ambulance personnel with the feeling of discomfort with triage systems in practice. There are several studies that have shown the poor use of triage tags [1, 82, 108, 113, 115, 122], but there are few studies that have investigated the reasons behind this. Several studies concern the validity of different triage systems [112, 182].The performance of triage, despite the absence of good evidence to support any particular triage system or tool, suggests that triage is based on relatively little scientific evidence. Several researchers highlight the need for accuracy of triage in medical response since it has crucial impact on patient outcome [5, 46, 63]. Furthermore, ambulance personnel expressed that maintaining card documentation in a stressful situation is perceived as taking time from the assessment and care of the patient. Frykberg [46] and Zoraster et al. [88] indicate several deficits in medical response in stressful situations including losing track of patients and the risk for inaccurate triage, treatment and record keeping. Studies of previous urban terrorism have identified a correlation between over-triage and subsequent overall mortality [46]. This can be related to the importance of rapid access to command and control at different levels, appropriate resource use, and transport of the patient to the most suitable healthcare facility. If performed timely and accurately, this has been shown to optimise incident outcome [82, 166]. In the Madrid train bombings 2004, described by Carresi [115] the majority of injured patients were evacuated to hospitals without triage or treatment, bypassing medical control. Written documentation of triage decisions and patient management is an essential tool, not only for maintaining continuity of care during major incidents but also for retrospective analyses of the accuracy of triage decisions.

Probably the most effective way to avoid unfavourable consequences is to train the complex relationships between actions, resources, and patient outcome. A useful triage system should be fast, easy to perform, reproducible and accurate [68]. Our results (IV) further indicate that difficulty, lack of time, sparsely written documentation and the lack of daily routine are related to how ambulance personnel experience the use of triage tags. The study suggests that the triage tool being used was too detailed, therefore causing ambulance crews to give low priority to the labelling of patients and written documentation. The triage tool used in this thesis (IV) has also been adopted in several other regions in Sweden, but so far a standard for disaster triage does not exist in Sweden. In conclusion, the current practice of labelling patients with triage tags and written documentation of measures taken is generally sparse in the SCC area.

Recent technological advances have provided innovative solutions, such as the technical support system Radio Frequency Identification system (RFID) (V). These advances might increase the use of triage and help in decision-making concerning patient management. The application of RFID technologies in healthcare has been modest, primarily due to cost issues [128]. A technical support system for continuous triage information and patient tracking was described and tested in Study V. The test results were promising. In this thesis (V) RFID increased the situational awareness at all management levels. Information about the numbers and triage categories of patients was available to the medical management command approximately one hour earlier than when using the traditional method with paper-based triage tags. The greatest chance of improving the survival of critically injured patients is during the first hour of rescue, which is why this “golden hour” is so important. Every hour saved means valuable time for preparing the distribution of critically injured patients to appropriate hospitals, thereby improving the chances of a better outcome.

When major incidents occur, high demands are put on the medical management system and leadership if one is to reach desired outcomes [98, 99]. It is evident that effective medical management relies on clear and effective inter-disciplinary communication, especially of critical information such as the triage categories of patients. During rapidly changing environmental conditions, reliable and timely situational awareness is crucial for making the correct decisions regarding the allocation of available resources. Resource allocation and continuous patient tracking is a significant logistics problem in major incidents [88]. To improve situational awareness, the ability to track patients, to appropriately record triage information, and to determine where resources are overwhelmed, we need to test different technical support systems. Triage is a dynamic process and patients are repeatedly re-triaged along the evacuation chain, including the receiving hospital, until definitive treatment is received [29]. As the triage information was available on line it was possible to make decisions based on up-to-date situational awareness at different management levels.

6.2 METHODOLOGICAL CONSIDERATIONS

6.3 DATA COLLECTION

6.3.1 Templates for the performance indicators

In Study I and II, templates for performance indicators were used to measure medical management in full-scale exercises. This instrument was developed by Rüter [172]and has been used in several Swedish and international studies [33, 40, 41, 72, 146, 158, 159]. These templates, however, have mostly been used in exercises in conjunction with training courses. The study of a complex phenomenon generally begins with observational studies, often presented in a descriptive manner. Many phenomena are difficult to describe and measure. If performed well, Hulley et al. [199] state that this can increase the objectivity of our knowledge. Well-defined sets of performance indicators may assure a fair and unbiased assessment of the phenomenon under study [156]. Performance indicators represent standards for initial decision-making and staff skill (time and content) measured by scores (0, 1 or 2). The outcome indicators measure the risk for preventable death or complication. This was done using the ETS. One disadvantage was that this simulation system may have limitations when evaluating patient outcome, but until studies from real incidents, where performance as well as outcome indicators are available, we believe that this method will provide valid results. In the decision-making process we also need to understand "why" since indicators only indicate - not explain. Qualitative indicators use category classification and are, by some analysts, defined as those based on individual perception, e.g. response to survey questionnaires. According to Blooms taxonomy, quantitative indicators presented numerically as a matrix, or "checklist", may only lead to learning without deeper knowledge [183]. This lack of qualitative aspects is a limitation of performance indicators. This can, however, be compensated for by using survey questionnaires or deep interviews. Another disadvantage is that indicators are not weighted according to their relative importance, and it could well be that some indicators are more important than others. Correlation studies may provide an answer to this. One advantage is that indicators make it possible to obtain objective results by providing a standard for decision-making. The continuous monitoring of indicators facilitates effective evaluation. One advantage of this study was that there were certified external instructors who could interpret the phenomenon under study, and knew how their observations should be recorded.This helps to ensure that each evaluator scores each process in the same way, making it possible to obtain valid data. The scoring of indicators provided a means for grading performance. Different evaluators may give different scores for different processes. Our findings indicate that this evaluation methodology can reach a consistent approach independent of which of the certified instructors performs the evaluation (I, II). This provided a less biased comparison of the two separate exercises, strengthening the feasibility of the findings.

Another benefit of Studies I and II concerns the sample characteristics i.e. representative participants. In these two full-scale exercises all participants were familiar with the management structure (doctrine) at major incidents. The indicators in these exercises corresponded to procedures in the initial disaster medical response according to the Swedish doctrine [56]. However, the critical problem in an observational study is to obtain similar experiment and control groups. Thus, the competency and quality between different levels of management and organisations may differ depending on the variation in the professional qualifications, education, experience and training in disaster medicine of those involved. This is a major weakness and can affect the validity of the procedure. The disadvantage of the present studies was that the pre-hospital organisations in Exercises I and II had different training concepts with regard to command and control. This could, to some extent, explain the high discrepancy in the pre-hospital command and control scores between Studies I and II. The advantage despite the different training concept, however, is that medical personal must follow the same regulations. The great discrepancy, however, stresses the importance of standardised education and training programmes in disaster medicine.

6.3.2 Mixed methods

Study IV combined quantitative and qualitative data. The findings reported were instrument scores and focus group interviews. In the process of obtaining more information on why responders scored as they did, we also wanted to obtain information on whether this information appears the same in interviews as it did in the quantitative measurement of the phenomenon under study. When quantitative results are confirmed by qualitative results the validity increases. Weaknesses in one method may be compensated by strengths in another. Research into diverse sources of data can provide a deeper insight into and interpretation of the phenomenon to be studied. For this reason, mixed methods often have a broader focus than a single design [184, 185]. Even if research workers intend to be as neutral as possible, consideration must be given to their preconception. The first author with experience and skills in the topic served as the focus group moderator, this may have imposed certain bias that reflected desired outcomes. However, an understanding of the phenomenon under study is an advantage in the process of sampling for complementary convergent validation. This was achieved by detailed information on whether participants regarded the phenomenon in the same way when they scored their answers in the survey as they did in the interviews [185].

6.3.3 Quasi-experimental

The quantitative part of Studies IV and V had a quasi - experimental design. Quasi-experimental designs share similarities with the traditional experimental or randomised controlled trial (RCT), although they specifically lack the element of randomisation to treatment or control groups. In an experiment participants are randomly assigned, but in a quasi-experiment, they are not. The allocation of participants to a group is often predetermined by the work organisation [186]. Quasi -experiments use the "pre-post testing" design, which mean identical tests are performed before and after the actual experiment. In Study IV we used a questionnaire before and after a time-limited intervention; the use of triage tags by the ambulance services in day-to-day practice. One disadvantage was the large drop-out and poor adherence to the intervention. In Study V a technical support system for triage in major incidents was tested and compared with a control group using traditional triage tags. The advantage was that the same system was used in similar settings with a representative sample. An exception was that the figurant sent the information via “triage-phones” themselves in Exercise 2 whereas in Exercise 1 this was done by medical personnel. The reason for this was that the medical personnel were not able to participate in the transmission of data and this should be seen as a disadvantage. Another disadvantage was the small number of exercises used for testing the system, which must be taken into account when drawing conclusions. Results from observational studies are commonly considered to be less reliable. According to Rosén et al. [187], however, there is a misconception that the only study design to be trusted, when it comes to intervention studies, is the RCT. The authors conclude that observational studies should be based on their methodological qualities, not the type of study design. Simulation models, if used correctly can support experimental research [188].

6.3.4 Questionnaires

The advantage of using questionnaires (IV) is that they can include a large number of respondents. The disadvantage is that the issues are dominated by the researcher´s pre-understanding in the selection and design of the questions. To minimize these problems pilot studies were performed. In the design of a questionnaire there are two basic forms of question; closed-ended and open-ended [189]. Both have several advantages and disadvantages. Closed-ended questions ask the respondent to choose their response from pre-selected answers. They lead respondents in a certain direction and do not allow them to express their own opinion as with open-ended questions. Closed-ended questions were used in Study IV as pre-and post surveys upon which the quantitative findings were based. In addition, a few open-ended questions provided the possibility for respondents to add extra information that could have been missed. When gathering information on peoples’ opinions, attitude survey questions or interviews are used to reveal people’s thoughts on a subject or phenomenon. Likert scales and other self-reports are commonly used. There is general agreement that attitude is an expression that reflects evaluation of a particular object (attitude object) that may vary from positive to negative e.g. good-bad, pleasant-unpleasant, harmful- beneficial, and likable-dislikable [190]. Basically, an attitude is an opinion or belief that motivate and determine the way people act. The sample size in Study IV was quite large. The web survey was distributed on-line and answered anonymously. To ensure an accurate and standardised response, instructions specifying how the questionnaire should be filled in were added to the survey. The advantage of using a web-based survey was that all ambulance nurses and physicians employed in the ambulance services in SCC could be reached. . The disadvantages were that the non-response rate was high and the web-based survey with some technical errors in connection with distribution which could have had an impact on the response rate. Another possible explanation is that participants may have dropped out because of the time period of nine months between the pre- and post surveys, and the fact that the data collection took place during a large reorganisation of the ambulance services at that time. The participants who continued may have been those who were most interested in the study. However, the issue of responder motivation and responsiveness is an important one for both traditional and web-based methods. Since either of these methods are presumably just as susceptible to non-responses or non-serious responses [204]. The focus group interviews were a significant complement to the web-based survey’s closed-ended questions.

6.3.5 **Focus group interviews**

The use of focus group interviews in Study IV seemed to be an appropriate method when explore hidden attitudes and experiences about topics that affect the duties of ambulance crews [173]. The point is to use homogeneous groups with similar background and experience. Unlike in-depth person- to-person interviews, the advantage of FGI is the interaction process that is able to explore hidden attitudes and disagreements about the topic in question [185]. A purposeful sampling strategy is recommended for information-rich situations where clarification rather than empirical generalisation is needed [173]. This type of sampling is particularly useful in studies on phenomena suchas the attitudes and experiences of practicing triage tagging in Study IV. In the literature, different authors give different advice regarding numbers of participants and focus group sessions. However, four to eight participants are considered to be optimal for a FGI, and that at least three focus group interviews should be included [185, 191]. The validity and meaningfulness, has more to do with the richness of information in the statements given by those in the group and analytical capabilities, than with sample size [173]. The number of participants per focus group in Study IV was found suitable. All FGIs were performed by the first author, with experiences and skills in the triage system and tool under study. A pre-understanding of the phenomenon discussed can be considered a strength, but it can also affect the direction of the interview. The interactions among participants were dynamic and focused, keeping to the topic. Patton [173] states that a interview guide is essential for keeping the interaction focused while allowing individual perspectives and experience to emerge. It is also important to create a secure environment for the participants so that they feel comfortable to share beliefs, ideas, attitudes and experiences with each other [192]. One advantage with focus group interviews is that individuals, who may feel insecure in a face-to-face interaction, feel more secure in contributing with their experiences in a group.

Furthermore, the group interaction provides the moderator, who is often the research worker, with an opportunity to hear issues which may not emerge from individual interviews. Focus groups do not aim to reach consensus on the interview topic, but rather encourage a range of responses which provide a greater understanding of the attitudes, experience, behaviour, opinions or perceptions of participants regarding the phenomenon to be studied. One disadvantage of focus groups may be that participants with dominant personalities may influence the group or that they can silence individual voices of dissent [191]. This situation slightly emerged in all group interviews but since the moderator was aware of this disadvantage it was a minor problem. At the end of the group session, the moderator briefly summarised the information gained for the group. This gave the group members the opportunity to clarify and correct any false information. An alternative to focus group interviews could have been individual interviews. Individual interviews might have given another dimension of insight and interpretation about the phenomenon studied. To strengthen the dependability of the study two research authors analysed the data independently and completed and described the analysis together so as to capture an overall impression of the text. The author's findings are admittedly subject to the biases inherent in qualitative research. In order to mitigate this bias the statements of participants were cited in the synthesised findings.

6.3.6 **Delphi technique**

In Study III the Delphi method was selected for data collection. This was done after extensive reading about different consensus methods such as Utstein-style, Nominal Group Technique (NGT) and the Delphi technique. The Utstein-style, a modified of NGT got its name after an international resuscitation meeting in 1990 at the Utstein Abbey, in Norway. The Ustein –style has recently been used for a international consensus process for uniform data reporting [50]. The Nominal Group Technique was developed in 1971 as a means for small groups to reach consensus [193]. The Delphi Method and the Nominal Group Technique are both techniques for achieving consensus within a group. The Delphi method was created to make accurate predictions of the future, while NGT was developed to prioritise issues within a group. Both techniques are iterative in nature where groups make initial assessments and then refine them as evaluations are shared within the group. One advantage of the Delphi method is that all experts have the same impact on the consensus process. The risk of influencing other participants is also reduced by avoiding face-to-face discussions [194].

Another advantage of this process is that the scoring is anonymous and experts can change their mind based on new data, without being questioned. Disadvantages of the method include issues such as anonymity, definitions of experts, how experts are selected, and how non-responders are pursued. According to McKenna the Delphi technique cannot guarantee complete anonymity and therefore uses the term “quasi-anonymity” [195]. The experts were aware of the others participating in the group, but their response to each questionnaire remained strictly unknown to each other. In the literature this quasi-anonymity is highlighted as a motivation factor for participation and may also increase the response rate [196, 197]. With this in mind, the authors believe that the experts’ awareness of each other’s participation in the same research project increased the response rate in this study. A strategic selection of experts was made with a broad requirement for knowledge and experience in the field of disaster medicine. An expert is difficult to define. In order to find and determine critical aspects of activities in DMR the experts needed to have a good knowledge of how the medical response system works. The majority of the participants selected had many years of experience in disaster medicine, and they were involved in these issues every day.

From this perspective their opinions and judgments can be seen as a valid representation of the needs and requirements regarding standard data for reporting a major incident. In the literature, a broad choice of experts with diverse expertise and geographic background is highly recommended [196]. The questionnaires were developed based on a review of the literature in the field. This could have introduced bias by causing the participants to feel pressed to alter their view on disaster medical response according to the authors’ predefined statements, even though they were given the opportunity to suggest new ideas. Our attempts to describe statements in an unbiased way may not have been successful in some aspects, as revealed by the experts’ comments. This emphasises the importance of ongoing discussion in order to reach clear and valid definitions, and the practical use of these terms as a base for management and performance in disaster medical response [17, 50]. The response rate was high, only one drop-out in Round 2. Another advantage was due to practicalities such as time and expense which made frequent face-to-face meetings infeasible. Group processes are expensive and if the consensus document is national or international, the cost of getting a group together may be expensive. However, in this setting, the Delphi technique was more time-consuming than the literature implies.

6.4 ISSUSES OF TRUSTWORTHINESS

In quantitative research concepts such as validity, reliability, and generalisability are used to establish trustworthiness [189]. In qualitative research the four concepts credibility, dependability, transferability and conformability are used to describe trustworthiness [198, 199]. In all studies reflections concerning chosen context, study design, data collection, participants and accurate measuring instruments, have been made and described. To strengthen the trustworthiness of Studies I and II standardised incident exercises with built-in evaluation methodology were used. In observational studies there are methodological considerations concerning reliability and therefore the assessment must be based on the quality of the study design [187]. To determine the validity and reliability of a study , the general approach is to find a suitable tool for the research that is to be validated [173]. The key to good indicators is internal validity. The advantage was that certified evaluators with interpretation of the phenomenon in question scored different processes in the same way, making it possible to obtain valid data. In this thesis three of five studies (I, II and V) used the same exercise setting to collect data which may be considered a methodological limitation regarding external validity. The reason why this was done is because full-scale exercises are seldom or irregularly performed, and compared to other forms of exercise, are much more expensive. In order to avoid possible weakness the study design of these full-scale exercises was: 1) standardized; 2) replicated under the same methodological conditions; 3) conducted in realistic settings in different geographic locations and time periods; and 4) using different representative participants. To be able to obtain reliability and generalisability the number of exercises must be repeated several times. To strengthen trustworthiness in Study III, the choice of experts and data collection method were important. Furthermore, the researcher's interpretation of the culture of participating organisations, and heterogeneous sampling can help to strengthen trustworthiness and minimise bias [196]. Although consensus was reached on 77 statements, we cannot be sure that the optimal key indicators have been identified, only that they reflect expert consensus in a Delphi study. It is therefore important that one acknowledges the influence of bias and the validity of the results when using the Delphi technique [11]. Kenney et al. [175] argue for that group opinions are more trustworthy than individual opinion. To strengthen the trustworthiness in Study IV the choice of context, participants, method of data collection, and the amount of data were important. A characteristic of qualitative research is that the researcher often also is the tool for data collection. Even if the researcher intends to be as neutral as possible, consideration must therefore be given to the researcher's pre-understanding and preconception. The findings were described so that the reader could follow the process of analysis used to judge the transferability and credibility. Credibility of findings also deals with the selection of the most suitable meaning unit, the dialog between the researchers before reaching agreement on categorization, and how well categories cover data [178]. In Study V the method for data collection, representative samples, consistency of the tool, reproducibility, and similar settings strengthen the trustworthiness. The strength was that the same technical support system was used in similar settings with representative samples. Although the results of this study lack rigorous comparison of the different triage and communication systems, the results provide a picture of the possibilities the technology offers.

6.5 FURTHER RESEARCH

To achieve greater acceptance of evaluation methods, valid and measurable indicator models must be promoted by healthcare providers. By using these indicators in the evaluation of real incidents, and comparing results with available patient data, it is possible not only to compare the performance of the indicators (I, II), but also to validate the outcome indicators chosen for the exercises (II). Comparison with real incidents gives us clues as to whether or not we are educating and training our personnel in the best possible way, and comparing results will provide information about improvements that should be made in the pedagogic educational simulation systems used today.

This will also reduce the time used for planning and after-action report writing. Indicators are now gradually being introduced in various regions in Sweden, for evaluating the effect of training in order to measure quality in performance related to management doctrine. In this thesis we have not considered structure indicators relating to personnel such as time and financial costs. Results from future studies using a systematic approach to structure indicators will provide important information on how training and exercises should best be conducted.

There is a need for a nationwide register to gather and validate the information we gain from major incidents. Based on the Delphi technique, Study III identified key indicators essential when registering incidents in the initial disaster medical response. This provides guidance as to what should be included in a nationwide register. These indicators will be presented to stakeholders at the national level, where the possibility of them being included in training as well as in practice will be discussed and further developed. Benchmarking, the collection of relevant data from many DMRs, allows comparison and the assessment of the strengths and weaknesses of the management structure, leading to systematic and steady improvement. Future research will demonstrate whether the results can serve as a base for a generally acceptable nationwide register, thus making participation and comparison in international studies more practical.

The challenge of the future is not only to validate triage systems, but also to focus on the importance of real-time information (situational awareness) so that healthcare facilities can respond effectively. Study IV provided essential information for understanding what is required for future improvement. Ambulance crews have a positive view on working with standardized, simple triage algorithm systems, but the lack of re-training, the format of present tags, and the lack of practise are the main obstacles to their use of triage tags. The participants' perceived that time used filling in tags may be better used caring for severely injured patients. However, if documentation is limited to triage tags, no central patient- related information is available, and paper-based tags are not directly visible to the incident officers. If triage has been an issue for the past 200 years, and still there is no study stating the use or benefit of triage tagging, perhaps it is time to challenge the whole idea. Future research must find new means of approach to address this issue.

Real-time information is critical for medical commanders who must coordinate up-to-date information on the number of patients and their need for resources available, with the capacity of the receiving healthcare facilities. This is based on rapid estimates of the number of patients and triage categories. Situational awareness in management systems, is often achieved through manual paper-based tracking systems and radio communication. Current technology provides the opportunity for creative solutions. New techniques for automatically spreading information among all personnel involved to save time and resources, enhance situational awareness, patient care and improve outcome have been tested (V). However, more tests in the field are needed.

In the future, the RFID triage system may be valuable tool in disasters and major incidents, as well as incidents with smaller numbers of casualties. A system used in the direct assessment of the patient, where ambulance personnel can begin the triage process and recording simultaneously, might be a way of increasing situational awareness at all levels of management. Furthermore, it is important that persons with knowledge on the subject are involved in the process of developing technical support systems.

7 CONCLUSIONS

In this thesis it is concluded that

- Standardised full-scale exercises in different settings can be conducted and evaluated using performance indicators combined with outcome indicators, enabling results from exercises to be compared. If exercises are performed in a standardised manner, results may serve as a basis for “lessons learned”. Future use of the same concept using the combination of performance indicators and patient outcome indicators may provide important evidence that could lead to new ideas and a better understanding that subsequently may be applied to real incidents.

- The Delphi technique can be used to achieve consensus on data, comprising key indicators that are essential for registering the response to major incidents and disasters. Study III identified key indicators essential for data reporting from the response of major incidents. Consensus at the national level can, in essential respects, be derived from the results of international studies. Future research will demonstrate whether the results from the present study can serve as a base for a generally acceptable national register, thus making participation and comparison in international studies more practical.

- Ways to document actions in the field must be improved so that retrospective analyses of triage decisions and the quality and accuracy of treatment can be carried out objectively by researchers. Real-time information is critical for medical commanders who must coordinate up-to-date information on the number of patients and their needs with resources available and the capacity of receiving health-care facilities. However, if documentation is limited to triaged patients’ tags, no central patient- related information is available to the incident commander

- Radio Frequency Identification is a feasible tool for providing situational awareness during disaster exercises. The system tested was easy to use, fast, stable, and worked smoothly, even in harsh field conditions. It surpassed the paper-based system in all respects apart from simplicity. It also improved the general overview of mass-casualty situations, and enhanced medical emergency readiness in a multi-organisational medical setting. Situational awareness at all hierarchical management levels was based on pooled real-time data generated at the scene of the incident. The timeliness of available information for disaster management was considerably better using the RFID system than using traditional paper-tag triage.

8 SVENSK SAMMANFATTNING

Bakgrund: God katastrofmedicinsk beredskap grundas på tillgången på sjukvårdspersonal som är utbildad och övad för att rädda liv. Träning och övning är viktigt för att säkerställa förmågan att organisera och leda sjukvårdsinsatser oavsett händelsetyp. Beslutsfattande på alla ledningsnivåer är baserat på tillgänglig information och innefattar omfördelning av medicinska resurser och beslut om prioritering mellan allvarligt skadade eller sjuka patienter. För att få en uppfattning om kvalitet och resultat rörande sjukvårdsinsatsen bör övningar utvärderas objektivt och baserat på fastställda standarder. Tagna beslut kan då utvärderas mot uppställda mål. Detta medger möjlighet att relatera tagna beslut till utfall dvs. resultatet eller hur det gick för patienterna. Avhandlingens övergripande syfte var att öka kunskapen om den kvantitativa utvärderingens betydelse vid sjukvårdsinsatser inom katastrofmedicinsk beredskap. **Metod:** Studie I, II och V bygger på strukturerade observationer av fullskaleövningar. Ett utvärderingsinstrument för att mäta kvalitén på genomförande av sjukvårdsledning på olika nivåer har använts i studie I och II samt ett simuleringssystem för att mäta resultatet av varje enskilt patientomhändertagande i studie II. Datainsamlingen för studie III baseras på Delfitekniken, en konsensus metod där 30 experter besvarade tre omgångar enkäter. Enkäterna innehöll påståenden om väsentliga komponenter ingående i en sjukvårdsinsats av betydelse för skapande av ett nationellt register. För studie IV genomfördes två datainsamlingar. Ett frågeformulär bevarades av ambulans-sjuksköterskor och läkare (n= 57 respektive 57) före och efter en tidsbegränsad strategi gällande användning av prioritetsmarkeringskort och tre fokusgrupp intervjuer med ambulanssjuksköterskor och ambulanssjukvårdare (n=21). Frågeformulären och intervjuguiden innehöll frågor gällande deras attityder och erfarenheter av att använda prioritetsmarkeringssystem vid prioritering mellan allvarligt skadade patienter. Datainsamlingen för studie V genomfördes på två simuleringsövningar med figuranter (n= 20 respektive 20) för att testa tillämpbarheten av en teknik kallad Radio Frequency Identification (RFID tags) och jämföra det med traditionella pappers baserade prioritetsmarkeringskort. Kvantitativ data analyserades med beskrivande statistik och kvalitativ data med innehållsanalys. **Resultat:** Utvärderingsmetoden påvisade ett antal brister i den initiala beslutsfattningen (I, II). Brister som observerades upprepade gånger och som hade stor påverkan på patient resultatet. Studie II visade att av 17 allvarligt skadade patienter riskerade fem respektive sju patienter att avlida. Totalt sett uppnådde experterna enighet kring 77 påståenden av 97 (III). Ambulans personalen tror på nyttan av standardiserade prioritetsmetoder men den låga användning tyder på att prioritetsmarkeringskort används sällan. Sällan användning gör att deltagarna inte upplever sig bekväma med att använda korten (IV). Radio Frequency Identification tekniken förbättrade lägesuppfattningen för katastrof ledningen. Prioritets information var tillgänglig mer än en timme tidigare jämfört med det pappersbaserade prioritetssystemet (V). **Slutsats:** Denna utvärderingsmodell kan användas på ett objektivt, systematiskt och reproducerbart sätt för att bedöma komplexa sjukvårdsinsatser, en förutsättning för kvalitetssäkring och identifiering av problem vid utvecklingen av katastrofmedicinsk beredskap.

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11 APPENDIX

11.1 TEMPLATES FOR THE PERFORMANCE INDICATORS

Appendix 1 Performance indicators for prehospital command and control

Performance indicators	Standard (time frame in min)	Score (2-1-0)
Putting on tabard*	Directly	
First report to dispatch	2 min	
Content of first report	METHANE**	
Formulate guidelines for response	3 min	
Establish contract with strategic level of command	5 min	
Liaison with fire brigade and police	5 min	
Second report from scene	10 min	
Content of second report	Verifying first report Indicating first patient transport	
Establish level of medical ambition	10 min	
First patient evacuated	15 min	
Information to media on scene	30 min	
		Total
		Approval level ➢ 11pts

*Vest, clearly labeled for identification of medical and ambulance staff.

** **M**ajor incident declared, **E**xact location, **T**ype of incident, **H**azards, **A**ccessibility, **N**umber of casualties, **E**mergency Services required. Acronym for the content, defined in the Major Incident Medical Management and Support Course (MIMMS).

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Appendix 2 Performance indicators for hospital management

Performance indicators	Standard (time frame in min)	Score (2-1-0)
Decide on level of preparedness	3 min	
Formulate guidelines for hospital response	15 min	
Inform media	15 min	
Give information about resources to strategic level	25 min	
Ensure that there is a medical officer in Emergency Operation	30 min	
Estimate need for ICU beds	45 min	
First information to staff	60 min	
Estimate endurance of staff	90 min	
Evaluate and report estimated shortage of own capacity	120 min	
Evaluate influence on daily hospital activities	120 min	
Information plan for patients with postponed appointments and operations	180 min	
		Total
		Approval level ➢ 11 pts

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Appendix 5 Performance indicators for strategic management

Performance indicators	Standard (time frame in min)	Score (2-1-0)
Declaring major incident	1 min	
Deciding levels of preparedness	3 min	
Decision on additional resources on scene	3 min	
Deciding on receiving hospitals	5 min	
Establishing contact with incident officers at scene	10 min	
Deciding on guidelines for referring hospitals	10 min	
Brief information to media	15 min	
Formulate general guidelines in accordance with guidelines from scene	15 min	
Make sure there is information for definitive referral guidelines	20 min	
Evaluated if capacity of own organisation is sufficient	30 min	
Notify guidelines on referring hospitals	40 min	
		Total
		Approval level ➢ 11 pts

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Appendix 6 Performance indicators for staff skills

Performance indicators	Standard Within…min from arrival on scene					Score (2-1-0)
Assigning functions to staff members	Directly on arrival					
Positioning in room in accordance to above	Directly					
Designated telephone numbers	Directly					
Introduction of arriving staff member	Max 1 min					
Utilisation of equipment * (only if equipment is available)	Whiteboard Flip-chart	Not	0	1	2	Average
	Fax					
	Computer					
	Other (specify)					
Staff briefing	Max 8 min					
Content of staff briefing **	Reports from staff members	Not	0	1	2	Average
	Summary					
	New assignments					
	Nest staff briefing					
Telephone discipline	(during staff briefing)					
Content of staff schedule	Staff briefings	Not	0	1	2	Average
	Media contacts					
	Meals					
	Staff relief					
Summary Verbal to staff members						
Summary Written to report						
						Total
						Approval level ➢ 11 pts

*Equipment available: whiteboard, flipchart, fax, and computer.

**Reports from all functions, summary, assigning new tasks, time for next briefing.

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